U.S. Department of Energy
Technical Qualifications

Mechanical Systems Topical Area

Self-Study Guide
and
Training-to-Competency Matrices

June 1996

FOR TRAINING USE ONLY

The uncontrolled information contained in this text is **FOR TRAINING USE ONLY**. In no way should it be interpreted that the material contained herein may be substituted for facility procedures or SOPs. When copies of SOPs or procedures are given, they are intended as examples and information only, and the latest revision of the material in question should be obtained for actual use. If you have any questions, contact your supervisor.

READ ME FIRST!

This study guide is designed to bring together information and references related to the topical area of Mechanical Systems. This document contains 29 competencies in 16 chapters. Each competency has the following sections: Supporting Knowledge and Skills, Self-Study Information, References, Practice Exercises, and Practice Exercise Answers. The Supporting Knowledge and Skills sections lists the applicable knowledge and skill statements that further describe the intent of the competency statements. The Self-Study Information is provided to help you refresh your knowledge of the information you need to know to be qualified in that competency. The References section lists the references for further study and information. The Practice Exercise section provides questions, practice exercise, scenarios, or case studies to assist study for the competency. Finally, the Practice Exercise Answers section provides answers to the Practice Exercise section. Additionally, an appendix provides the Training-to-Competency Matrix listing related courses and other activities that address the competency requirements.

COMPETENCIES - Which ones are mine?

The wording of the competencies found in this study guide may not exactly match those found in your Functional Area Qualification Standard. A number of similar competencies from across nine functional areas were consolidated to reduce the bulk and repetition of the material. To identify which of the 29 topical competencies in this Guide match the mechanical systems related competencies from your Functional Area Qualification Standard, use the matrixes on pages xii, xiii, xiv, and xv.

PLEASE NOTE- Not all Knowledge and Skills items identified in the Functional Area Qualification Standards are addressed in the Topical Area Study Guide. Employees are not required to demonstrate competency to the knowledge and skill level in order to qualify, only to the competency level. Ensure that you refer to your Functional Area Qualification Standards and compare those required Knowledge and Skills to the Knowledge and Skills identified in this Study Guide. The Topical Area Competencies in this self study guide list the applicable Functional Area and identify the Functional Area Competency as FAC# X.X.

WHAT REFERENCES DO I USE?

References used in this study guide are designed to be used throughout the DOE complex when possible. In some cases it is necessary to use site specific documents to provide information which more fully explains the intended knowledge and skills. For example, if a skill is to complete a report - those reports would be specific for a given site. In these situations a site specific reference will be given. In order to gain the most value from the self-study, when a site specific document is referenced, you should identify your own program/operations/field office specific reference(s) which support the requirements of knowledge and skill statement. In the event that a knowledge or skill is such that the only available references are site specific and would not necessarily change from one site to another, the reference will be identified and will accompany the study guide for your use.

This page is intentionally blank.

U.S. Department of Energy
Technical Qualifications

Mechanical Systems
Topical Area

Self-Study Guide
Introduction

June 1996

This page is intentionally blank.

TABLE OF CONTENTS

LIST OF FIGURES

Mechanical Systems

A. **Introduction**

1. Scope and Background

The scope of this study guide is to describe requirements for understanding Mechanical Systems within the Department of Energy (DOE) nuclear facilities. This study guide provides the participants with the required Competencies, Knowledge and Skills, Self-Study Information, and Practice Exercises necessary for the basic understanding of mechanical systems and components. This study guide provides the knowledge and references for personnel to more fully understand the operation of mechanical equipment for the safe and reliable operation of a facility.

This study guide has been developed to support personnel in their efforts to become more technically competent and complete the requirements of DOE's Technical Qualification Program. By providing competencies for which conduct and operation of mechanical systems can be implemented, a uniform process and program can be established for defense nuclear facility technical personnel.

The competencies developed for this study guide identify a familiarity level; a working level; an expert level of knowledge or skill; or they require the individual to demonstrate the ability to perform a task or activity. These levels are defined as follows:

Familiarity level is defined as a basic knowledge of or exposure to the subject or process adequate to discuss the subject or process with individuals of greater knowledge.

Working level is defined as the knowledge required to monitor and assess operations/activities, to apply standards of acceptable performance, and to reference appropriate material and/or expert advice as required to ensure the safety of Departmental activities.

Expert level is defined as a comprehensive, intensive knowledge of the subject or process sufficient to provide advice in the absence of procedural guidance.

Demonstrate the ability is defined as the actual performance of a task or activity in accordance with policy, procedure, guidelines, and/or accepted industry or Department practices.

Due to the administrative nature of some topics of Mechanical Systems, in certain cases there is no upper tier DOE related material available as reference for certain Knowledge and Skills. As a result, site specific reference material has been cited. It is the responsibility of the participating individuals to obtain their version of the referenced material used at their site/program office to assist them in understanding the Knowledge and Skills as required. To assist the participants with this study guide, a copy of the specific Savannah River Site materials have been included.

Due to the lack of appropriate technical information and documentation to support the knowledge and skills of some competency statements, some skill and knowledge statements were omitted from this version of the self study guide. Should this information become available it will be incorporated in the next revision of this document.

2. Purpose

   The purpose of this study guide is to assist personnel in preparing to demonstrate their competency in the area of knowledge of mechanical systems within the Department of Energy (DOE) complex. This study guide provides the fundamentals for consistent techniques and processes, and allows the participants to focus on performance and effectiveness rather than simple compliance with requirements.

   This study guide also provides a matrix of related mechanical system training courses available to the participants. The listed courses, in conjunction with the Self-Study Information can be used to satisfy and enhance the competency requirements.

3. How to Use This Guide

   a. Read this guide for those competencies you wish to satisfy through self-study. Review the associated Knowledge and Skills, Self-Study Information, and the items identified in the Reference section. Review the Self-Study Information in this guide, or in the referenced training material. For assistance or additional information, contact your supervisor or subject matter expert at your facility or site, or refer to identified resources in the Training-to-Competencies Matrix located in Appendix B.

   b. Work through the Practice Exercises provided in the document, filling your responses in the space provided. When complete, check your answers against the answers provided in the back of the competency.

   c. Refer to the Glossary (Appendix A), as needed, which contains definitions and terminology.

4. Functional Area Competencies-to-Study Guide Competencies Matrix

   a. Use the matrix on the following pages to determine which competencies in this document you are required to complete. Identify the functional area you are assigned to in the left hand column. Go across that row until you reach a box with a number in it, that number represents the Functional Area Competency number (FAC# x.x). From that box go up the column until you reach the top of the column, the number at the top of the column represents the Topical Area Competency number. Repeat this process for each competency in your row. Locate and study those Topical Competencies in this Self Study Guide.

      Example: Locate the Nuclear Safety Systems functional area. Notice that in the sixteenth column to the right is the number 1.9. Proceeding to the Study Guide Competencies at the top, Nuclear Safety Systems personnel are required to complete Competency 1.16 in this document.

   If there are no numbers in the row that contains your functional area then this document does not apply to your functional area and you are not required to complete any material in this document.

      Example: Locate the Technical Manager functional area. Notice that there are no numbers in the row to the right of the Technical Manager functional area, this means there are no competencies in this document that the Technical Manager is required to complete.

MATRIX FUNCTIONAL AREA COMPETENCIES-TO-TOPICAL AREA STUDY GUIDE COMPETENCIES

TOPICAL AREA STUDY GUIDE COMPETENCIES

FUNCTIONAL AREA	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17
General Technical Bases																	
Facility Representative			1.5		1.4		1.2 1.6		1.2			1.6		1.3		1.7	
Technical Manager																	
Technical Training																	
Radiation Protection																	
Environmental Restoration																	
Waste Management																	
Environmental Compliance																	
Fire Protection																	
Emergency Management																	
Occupational Safety																	
Industrial Hygiene																	
Nuclear Safety																1.9	

CONTINUED ON NEXT PAGE

MATRIX FUNCTIONAL AREA COMPETENCIES-TO-TOPICAL AREA STUDY GUIDE COMPETENCIES

FUNCTIONAL AREA	TOPICAL AREA STUDY GUIDE COMPETENCIES																	
	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.29						
General Technical Bases																		
Facility Representative	1.1					1.21												
Technical Manager																		
Technical Training																		
Radiation Protection																		
Environmental Restoration																		
Waste Management																		
Environmental Compliance					1.5													
Fire Protection																		
Emergency Management																		
Occupational Safety																		
Industrial Hygiene																		
Nuclear Safety					1.11													

MATRIX FUNCTIONAL AREA COMPETENCIES-TO-TOPICAL AREA STUDY GUIDE COMPETENCIES

TOPICAL AREA STUDY GUIDE COMPETENCIES

FUNCTIONAL AREA	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17
Nuclear Weapons Safety																	
Civil/ Structural Engineer																	
Project Management	1.1								1.1							1.1	
Safeguards and Security																	
Electrical Systems																	
Instrumentation & Controls			1.17		1.17		1.17							1.17			
Facility Maintenance	1.5		1.2		1.6		1.1		1.1			1.5 1.7		1.5		1.4 1.7	
Construction Management	1.24 1.25		1.24		1.24		1.24		1.19			1.24		1.24		1.24	
Mechanical Systems		1.6		1.3 1.9		1.8		1.2		1.1	1.18		1.10		1.7		1.5 1.11
EH Resident			1.5		1.4		1.2		1.2					1.3			1.6
Chemical Processing																	
Nuclear Explosives																	

CONTINUED ON NEXT PAGE

MATRIX FUNCTIONAL AREA COMPETENCIES-TO-TOPICAL AREA STUDY GUIDE COMPETENCIES																		
	TOPICAL AREA STUDY GUIDE COMPETENCIES																	
FUNCTIONAL AREA	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.29						
Nuclear Weapons Safety																		
Civil/ Structural Engineer																		
Project Management					1.1													
Safeguards and Security																		
Electrical Systems																		
Instrumentation & Controls			1.3		1.17		1.21											
Facility Maintenance							1.19											
Construction Management							1.7											
Mechanical Systems		1.6		1.4		1.22		2.1	4.1	2.10t hru 2.17	1.21	4.9						
EH Resident							1.14											
Chemical Processing																		
Nuclear Explosives																		

5. DOE Orders in Transition

DOE Orders are in a stage of transition. However, Order cancellation does not necessarily mean that the Order is no longer in effect. For example, DOE Order 440.1, *Worker Safety and Health Program,* which cancels seven occupational safety-related Orders, states:

> "Cancellation of an Order does not, by itself, modify or otherwise affect any contractual obligation to comply with such an Order. Canceled Orders that are incorporated by reference in a contract shall remain in effect until the contract is modified to delete the reference to the requirements in the canceled Orders."

This study guide refers to both old and new Orders. There are three reasons for this: (1) as stated above, many facilities are contractually obligated to follow the old Orders, (2) the replacement process is dynamic and will continue for some time, and (3) the old Orders are often content-oriented and house the in-depth details regarding processes and procedures.

Rather than publish a matrix of new and old Orders within this study guide, participants should refer to the document *"Crosswalk of Old Directives Numbers to New Directives Numbering System."* This is an excellent resource. It is linked to the DOE homepage "Clearinghouse for Training, Education, and Development" or may be reached directly at the following gopher site:

> gopher://VM1.HQADMIN.DOE.GOV;70/00/doemenu1/directiv/251cross.asc

Many of the referenced materials are available by accessing World Wide Web sites supported by DOE and other organizations. The constantly evolving nature of the Internet makes it impossible to guarantee the continuous existence of any referenced site, but some of the more helpful sites are included here:

- American National Standards Institute - http:www.ansi.org
- Department of Energy (DOE) Home Page - http://www.doe.gov
- DOE Clearinghouse for Training, Education and Development Home Page - http://cted.inel.gov/cted
- DOE Course Index - http://cted.inel.gov/cted/crsindex.html
- DOE Office of Training HRD, EH Training Material Page - http://cted.inel.gov/cted/eh_mat.html
- DOE OpenNet Database - http://apollo.osti.gov/html/osti/opennet1.html
- FedWorld Home Page - http://www.fedworld.gov
- U.S. House of Representatives Code of Federal Regulations - http://www.house.gov

6. Activities Following Completion of this Guide

   a. When you are ready to be evaluated on the competency(ies) applicable to your functional area, notify your supervisor, who will determine how you will be evaluated. This could include a written exam, oral checkout, or a walkdown. Note that this evaluation may be delegated by your supervisor to another DOE organization or individual (subject matter expert).

   b. Upon successfully demonstrating your competence to the evaluator, your Technical Qualification Record will be updated to document the completed competencies. The evaluator will sign off on the designated competency(ies) identified on this matrix.

This page is intentionally blank.

U.S. Department of Energy
Technical Qualifications

Mechanical Systems Topical Area

Self-Study Guide
Competencies

June 1996

This page is intentionally blank.

B. **Competency 1.1**

Construction management and engineering (FAC# 1.24 & 1.25), Facility maintenance management (FAC# 1.5), and Project management (FAC# 1.1) personnel shall demonstrate a familiarity level knowledge of general piping system construction, operation, and installation.

1. Supporting Knowledge and Skills

   a. Define the following terms as they relate to piping systems:

      - Pipe schedule
      - Water hammer
      - Hydrostatic test pressure
      - Laminar flow

        DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Module 3, Fluid Flow, Chapter Two Phase Fluid Flow and Chapter Laminar and Turbulent Flow.
      - Turbulent flow

        DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Module 3, Fluid Flow, Chapter Two Phase Fluid Flow and Chapter Laminar and Turbulent Flow.

   b. Discuss the various materials used in piping systems with regard to application, benefits, and limitations.

   c. Discuss the piping requirements for a given system application with respect to piping size, material and support.

   d. Identify and discuss the typical causes and potential hazards of water hammer and pressure spiking in piping systems.

   e. Discuss the purpose of seismic restraints (i.e., whip restraints or snubbers) in piping systems.

f. Discuss the following elements and components of mechanical system piping design. Include a discussion of construction methods used in the installation of each component:

- Pipe hangers
- Piping supports
- Snubbers
- Piping insulation and vapor barriers
- Piping installation
- Piping anchors
- Piping material
- Field routing of piping
- Expansion joints

g. Discuss the following types of piping connections and their application to different piping sizes and uses:

- Threaded connections
- Flanged connections
- Socket welded connections
- Butt welded connections
- Reweldable joints
- Bayonet joints
- Compression joints

h. Describe the basic construction methods and precautions associated with the installation of the following types of mechanical components:

- Large pumps
- Heat exchangers
- Air conditioning units
- Compressors
- Tanks and pressure vessels

C. **Competency 1.2**

Mechanical systems (FAC# 1.6) personnel shall demonstrate working level knowledge of general piping systems and piping system maintenance.

1. Supporting Knowledge and Skills

   a. Define the following terms as they relate to piping systems:

   - Pipe schedule
   - Water hammer
   - Hydrostatic test pressure
   - Laminar flow

     DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Module 3, Fluid Flow, Chapter Two Phase Fluid Flow and Chapter Laminar and Turbulent Flow.
   - Turbulent flow

     DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Module 3, Fluid Flow, Chapter Two Phase Fluid Flow and Chapter Laminar and Turbulent Flow.

   b. Discuss the potential hazards to personnel and equipment associated with water hammer.

   c. Identify and discuss the typical causes of water hammer in piping systems.

   d. Discuss the purpose of seismic restraints (whip restraints or snubbers) in piping systems.

   e. Describe the principle of operation for the various methods of measuring piping system parameters (e.g., pressure, temperature, flow) to include:

   - Resistance Temperature Detector (RTD)

     DOE Fundamentals Handbook Instrumentation and Control (DOE-HDBK-1013/1-92)Volume 1 of 2, Module 1, Temperature Detectors, Chapter Resistance Temperature Detectors (RTDs).
   - Differential pressure detector

     DOE Fundamentals Handbook Instrumentation and Control (DOE-HDBK-1013/1-92), Volume 1 of 2, Module 2, Pressure Detectors, Chapter Pressure Detectors.

- Pitot tube
  DOE Fundamentals Handbook Instrumentation and Control (DOE-HDBK-1013/1-92), Volume 1 of 2, Module 4, Flow Detectors, Chapter Head Flow Meters.
- Thermocouple
  DOE Fundamentals Handbook Instrumentation and Control (DOE-HDBK-1013/1-92), Volume 1 of 2, Module 1, Temperature Detectors, Chapter Thermocouples.
- Bourdon tube pressure gauge
  DOE Fundamentals Handbook Instrumentation and Control (DOE-HDBK-1013/1-92), Volume 1 of 2, Module 2, Pressure Detectors, Chapter Pressure Detectors.
- Duplex pressure gauge
- Manometer

f. Identify and discuss different methods of pipe joining (threaded, bull weld, socket weld, etc.).

2. Self-Study Information

Competency 1.1 and 1.2 address the knowledge of the principles associated with general piping systems. Competency 1.1 at a familiarity level and Competency 1.2 at a working level of knowledge.

The supporting material for the Self-Study Information include the following documents:

- DOE Fundamentals Handbook Instrumentation and Control (DOE-HDBK-1013/1-92) Volume 1 of 2.
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93), Volume 1 of 2, Mechanical Science
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93), Volume 2 of 2, Mechanical Science
- Westinghouse Savannah River Company Core Fundamentals Training Program Instrumentation and Controls Student Text (TTFGIC1A.H0100)
- Westinghouse Savannah River Company Core Fundamentals Training Program Fluid Flow Level A Student Text (TTFGFF1A.H0100)
- Westinghouse Savannah River Company High Level Waste Operator Training Program Applied Heat Transfer and Fluid Flow Study Guide (WGACFA06)
- Westinghouse Savannah River Company Core Fundamentals Training Program Fluid Flow Level A Student Text (TTFGFF1A.H0100)
- American Society of Mechanical Engineers (ASME) Code ASME Building Services Piping

- American Society of Mechanical Engineers (ASME) Code ASME B31.3 - Chemical Plant and Petroleum Refinery Piping
- American Society of Mechanical Engineers (ASME) Code B31.1 Power Piping
- American Society of Mechanical Engineers, Boiler and Pressure Vessel Code (ASME BPVC).
- Bureau of Naval Personnel (Revised 1971). Fireman Rate Training Manual (NAVPERS 10520-D). Washington, DC: Training Publications Division. Stock Order No. 0500-137-1010.
- DOE Instrumentation and Control Topical Area Self-Study Guide SR-TA-I&C-SSG-01.
- DOE Order 6430.1A General Design Criteria Division 15 Mechanical , Section 1525 Mechanical Insulation.
- Lamit, Louis Gary (1984). Pipe Fitting and Piping Handbook. Englewood Cliffs, NJ: Prentise-Hall. ISBN 0-13-676602-1.
- Loomis A. W., (1982). Compressed Air and Gas Data. Washington, NJ: Ingersoll-Rand Company.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.
- Nayyar, Mohinder, P.E. (1992). Piping Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8.
- Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications.
- Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15140-01-R, Field Fabrication and Installation of Pipe Supports.
- Westinghouse Savannah River Site Engineering Requirement Document No. M-SPC-G-00021, Generic Specification of Mechanical Equipment.
- Westinghouse Savannah River Company Engineering Requirements Document Number 15060-01-R, Process and Service Piping, Section 9.1.3.1 Maximum Test Pressure.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15020-01-R, Installation of Mechanical Equipment.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15060-01-R, Process and Service Piping.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15020-01-R, Installation of Mechanical Equipment.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15250-01-R, Mechanical Insulation.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15140-01-R, Field Fabrication and Installation of Pipe Supports.

- Westinghouse Savannah River Site Engineering Requirement Document No. 15060-01-R, Process and Service Piping.

Pipe schedule -

Pipe diameters set by American National Standards Institute. Wall thickness varies with schedule number. As thickness changes the inside diameter varies. Standard wall (SW), extra strong wall (XS), and double extra strong wall (XXS). Or extra heavy wall (XH) and double extra heavy wall (XXH).

Schedule - measure of the relationship of the wall thickness of the pipe to the inside diameter

Schedule number - approximation of the value of the ratio of the service pressure in a pipe divided by the allowable stress in the pipe multiplied by 1000. # = pressure/stress * 1000.

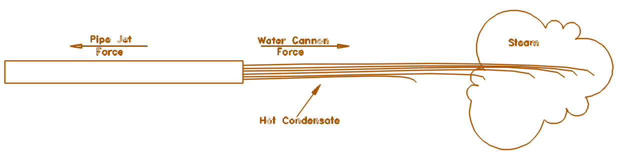
ANSI B36.10 standardizes the pipe dimension through out the industry.

Schedule describe the size of the pipe. As the schedule number increases the wall thickness increases. The outside diameter stays constant the inside diameter gets smaller.

Example of
Pipe Dimensions of a 1" Nominal Pipe Size Steel Pipe
with Different Schedules

	Schedule 40 (STD) or standard	Schedule 80 (XS) or extra strong or heavy duty	Schedule 160 test pressures	Schedule (XXS) or double extra heavy
Outside Diameter (OD)(in)	1.315"	1.315"	1.315"	1.315"
Inside Diameter (ID)(in)	1.049"	0.957"	0.815"	0.599"
Area Inside Pipe	0.86 in^2	0.72 in^2	0.52 in^2	0.28 in^2

Pipe whip - the displacement of piping created by the reaction forces of a high velocity fluid jet following a pipe rupture.



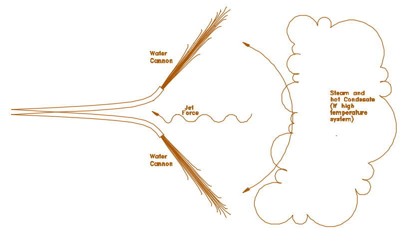


Figure 2 Pipe Whip

Figure 1 Water Cannon

Water hammer - is a liquid shock wave resulting from a sudden starting or stopping of flow. Water hammer is a physical shock to the components of a system caused by the impact of high velocity liquids or pressure waves.

Causes of water hammer - the liquid shock wave can result from a sudden starting or stopping of flow. Water hammer maybe caused by air present in a system due to improper venting; formation of steam in a fluid system; condensation of liquid in a steam system; or rapid operation of valves.

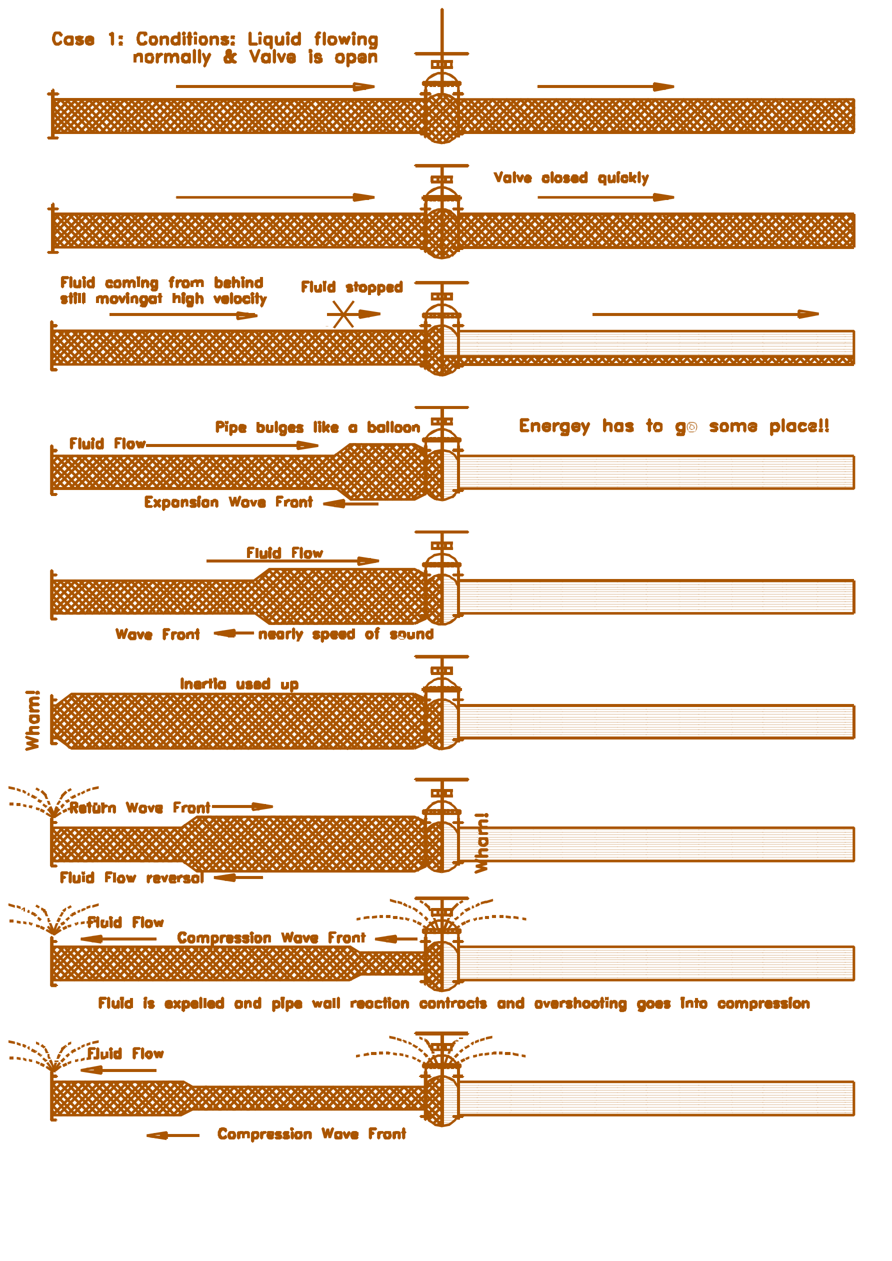


Figure 3 Valve Closure Induced Water Hammer

Hazards of water hammer - in pipes has been known to pull pipe supports from their mounts, rupture piping, and cause pipe whip. In extreme cases personnel injury and death have resulted from the failure of components due to water hammer.

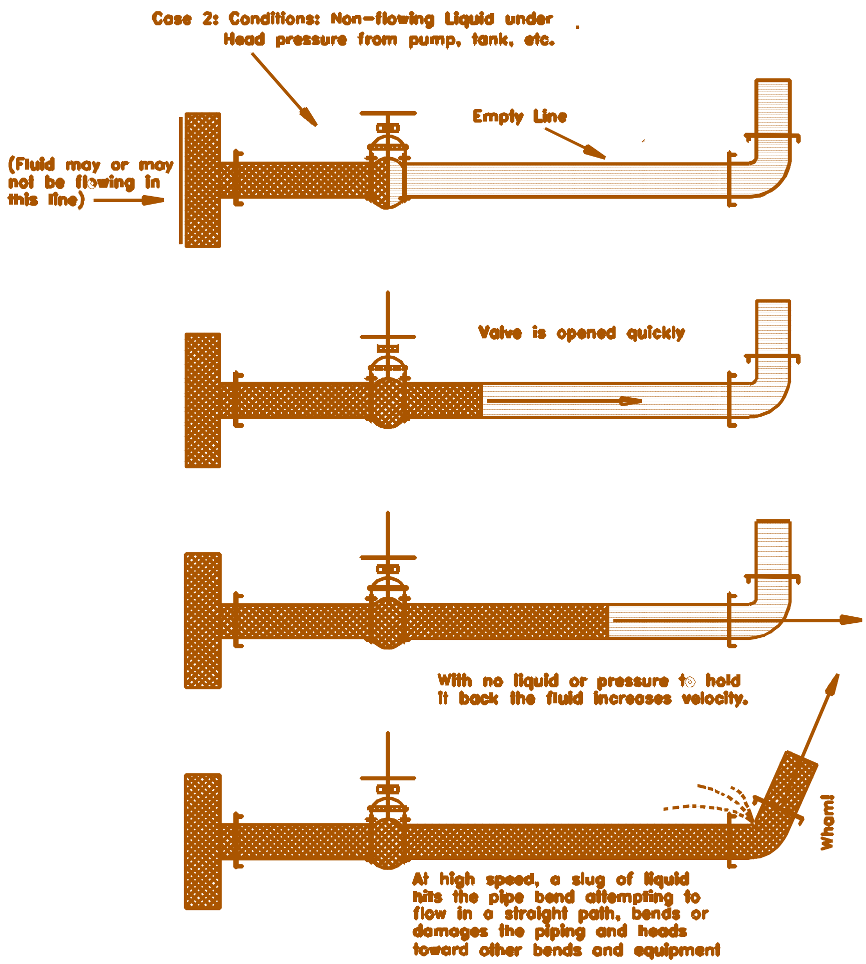


Figure 4 Water Hammer in Low Pressure Piping

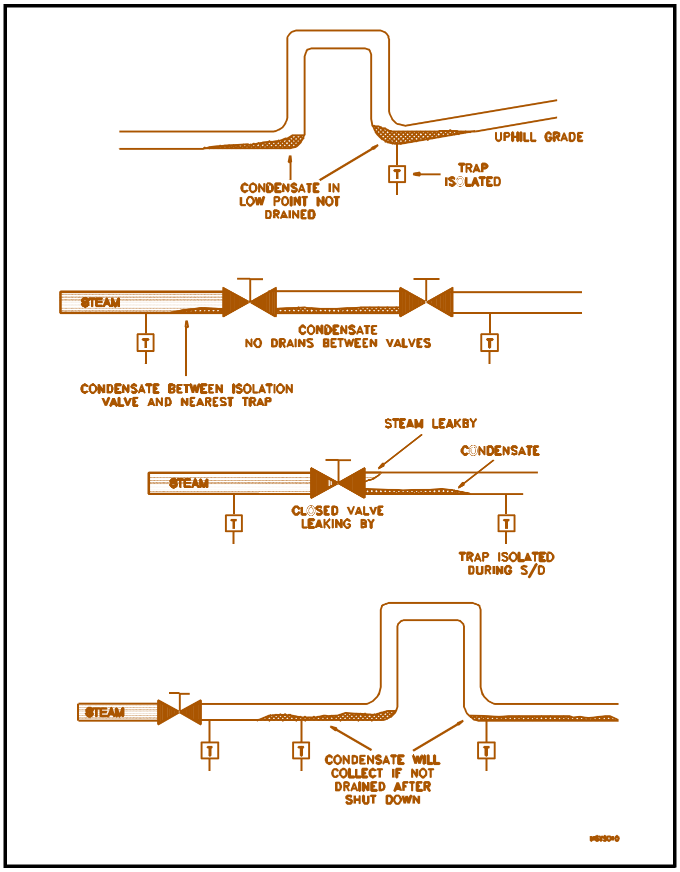


Figure 5 Potentials for Water Hammer

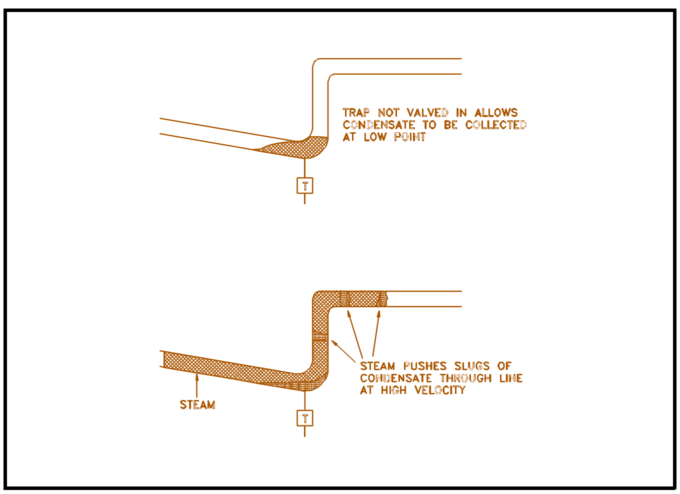


Figure 6 Condensate Induced Water Hammer

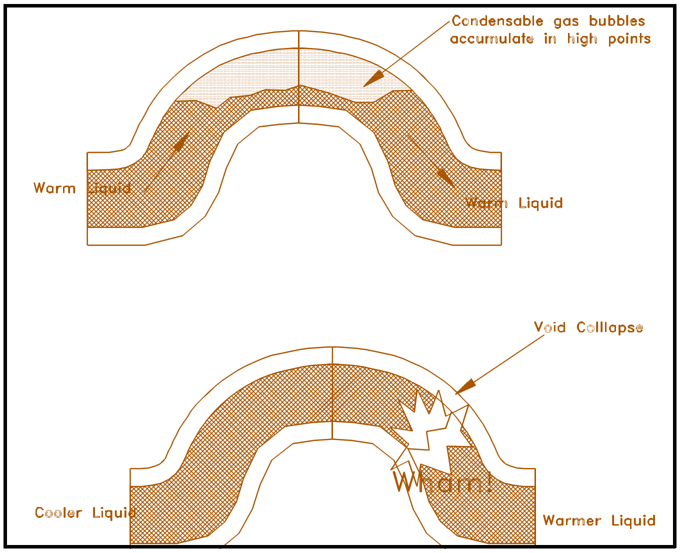


Figure 7 Water Hammer

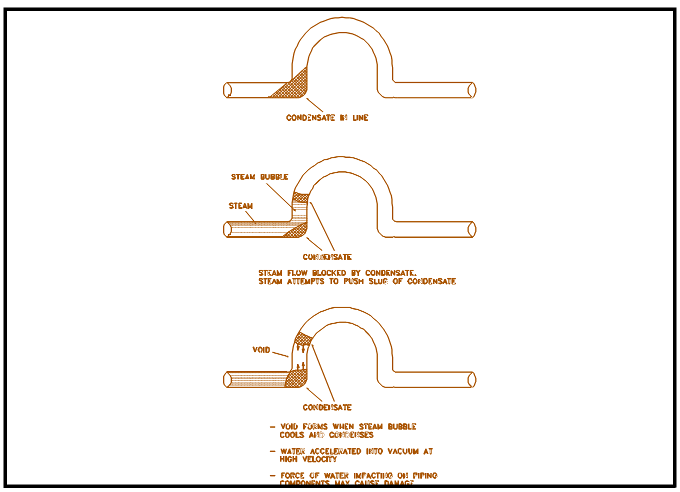


Figure 8 Condensate Induced Water Hammer

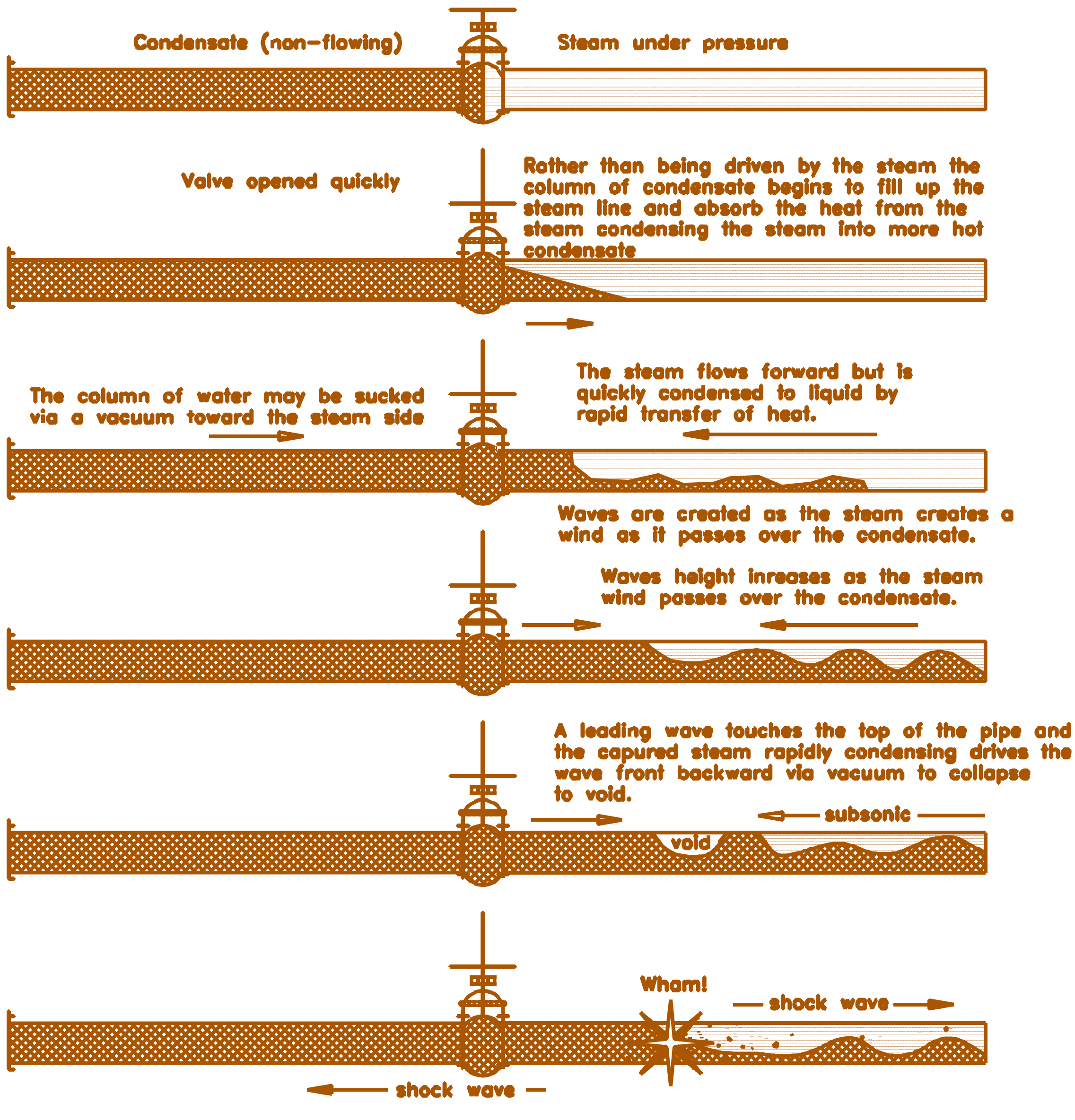


Figure 9 Condensate Induced Water Hammer

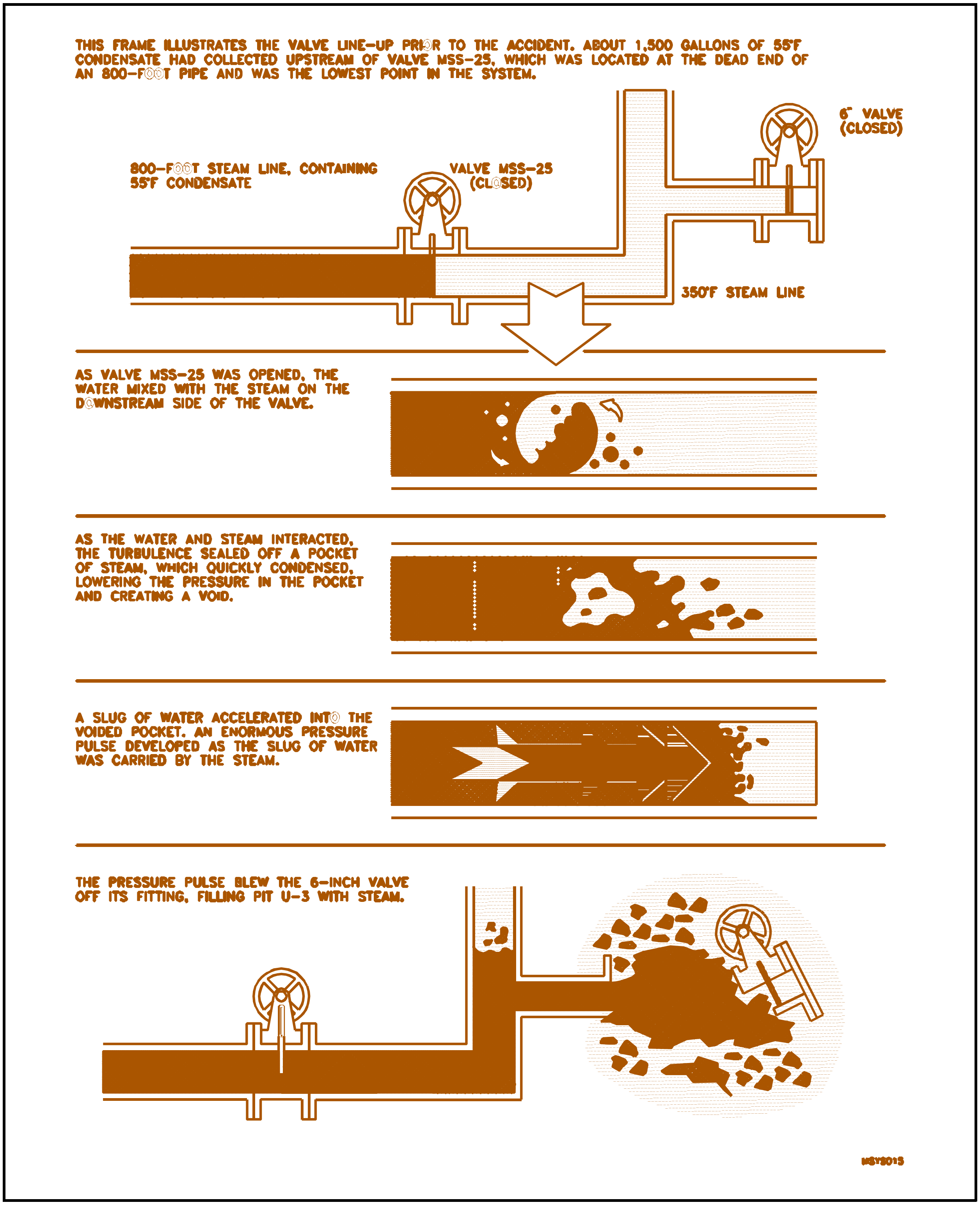


Figure 10 Hanford Condensate Induced Water Hammer Incident

Hydrostatic test pressure - is the pressure applied to a system to test the pressure boundary of the system. All non-isolatable components within the test bound are to be elevated for limitations of the maximum test pressure. The maximum test pressure shown is hydrostatic unless identified by the Piping Code (P-Code). Individual components can be bench tested when removed from the system for maintenance or repair. When the system has been re-installed the entire system can be pressurized and tested to ensure the system has adequate pressure boundary integrity.

A very important task to be performed when putting a new piping system into service or after service to an existing system is the hydrostatic test. This is a recommended test which subjects the system to cyclical and constant pressures over a specified time period. The test pressure must not be so high as to damage components of the system but high enough that bad joints and leaks can be found prior to placing the system into service.

Piping requirements for a given system

Piping requirements with regard to piping size, materials and support are dependent upon the application for which it will be used. Parameters that must be considered when identifying pipe for use in a specific application include:

Will the piping be used in a:

- Power application such as, external boiler piping, boiler blowoff and blowdown, steam, condensate or feedwater,
- Chemical plant of Refinery Piping systems intended for use with chemicals and related produces, flammable, toxic, or radioactive fluid service.
- Building services system to include fire protection systems, standpipe and hose systems.
- Operating Pressures of the systems.
- System Contents (i.e., gas, liquid, etc...)
- Environment of the systems.
- Specific application of the system piping.

Because of the extensive nature of this topic it is impossible to identify all of the potential combination of applications piping is addressed in several different documents. Further discussion of piping selection and use criteria can be found in the American Society of Mechanical Engineers (ASME) code B31.1 Power Piping, ASME B31.3 - Chemical Plant and Petroleum Refinery Piping, or ASME Building Services Piping.

Piping Materials -

Piping classified into three categories: rigid, semi-rigid (or tubing), and flexible (or hose).

Wrought Iron and steel majority of piping manufactured. Available indifferent grades. ASTM provides standards for piping material specifications. Commonly used for water,steam,oil, and gas services. (WOG water-oil-gas). Good because of high temperature and pressure characteristics. With added metal alloys better strength available.

Cast iron. Commonly used for water, gas, and sewerage. Especially in underground applications. Excellent resistance to external destructive forces. Not for high temperature, pressure, or vibration applications.

Steel. Typically used for rigid piping applications relatively large sizes. Benefits inexpensive material, can handle large volumes, can be used for long lengths, handles high pressures, and many fluids. Limitations: considerable installation costs, and corrosion concerns.

Brass and copper. Used where long life expectancy justifies the cost. Used in chemical and pulp applications because material can handle chemical solutions. Not for use >400°F. Must be supported at more frequent intervals, as the pipe is not as strong.

Copper: Typically used for semi-rigid applications (tubing). Size measured based on outside diameter dimensions. Commonly used for pneumatic circuits. Used for water and sewage piping, general heating and plumbing applications. Soft tubing used where equipment vibration present. Used in hydraulic, automotive, and pneumatic applications. Excellent when carrying solutions containing salts as resistant to corrosion. If connected to steel piping requires protection from galvanic corrosion.

Lead. Used in chemical systems as lead piping or lead lined piping resistant to chemical action of acids.

Aluminum 1/3 the weight of comparable steel piping. Affected by temperature so design must evaluate the temperature and pressure situations. Typically only used in low pressure systems.

Stainless steel. Common alloy used in nuclear field and special situations.highly resistance to corrosion mainly due to chromium added to alloy. Resistant to oxidizing solutions.

Alloys. Highly corrosive environment, shock (thermal and mechanical) and high temperature and pressure applications use special alloy piping. Solution, concentration, and velocity must be evaluated. Resistance to corrosion often based on formation of oxide layer of piping. At high velocity fluid may remove oxide layer preventing protection from corrosion. Thermal and mechanical shock also affect protective layer.

Titanium. Exotic metal found in use in chemical and pulp industries.

Plastic. Commonly used as it is inexpensive and easy to install. Resistant to many corrosive environments. Four main types: nylon, polyvinyl chloride (PVC), polyethylene, and polypropylene. Nylon used in low pressure applications (to 250 psi) and temperature between -100°f to 225°F. Not effected by most hydraulic fluids. Polyvinyl chloride (PVC) piping most widely used. Very tough resistant to chemical attack. Polyvinyl chloride commonly used for air line with pressure to 125 psi and temperature less than 100°F. Polyethylene commonly used for pneumatic services and miscellaneous fluids at low pressure. Sizes up to ½" OD. Polypropylene temperature between -20°F to 280°F. Sizes up to ½" OD. Fluorocarbon piping most resistant to acids, alkalies, and organic compounds. Petroleum products and chlorinated hydrocarbons handled by most but not all plastic piping. Can be used as liners in high pressure low temperature steel pipe. Deteriorates with exposure to sunlight. Cannot be used in high temperature applications. Must balance low initial cost with replacement cost.

Glass. Resists many acidic solutions. Used through chemical industry. Limited to <400°F pressure and vibration concerns must be considered. Used in chemical, beverage, pharmaceutical, and food industries.

Clay. Used for sewage, industrial waste, and water storage applications. Clay strong chemical resistant composition. Can transport most chemicals except hydrochloric acid.

Wood. Used through out history, primarily used to transport water. Manufactured by boring out solid logs. Municipal water supplies, sewers, mining, irrigation, and hydroelectric facilities.

Seismic restraints -

Seismic restraints are used in piping systems whenever there is a need to provide support for or restrain a dynamic loads. These loads may be as a result of seismic events but may also be due to water hammer, steam hammer, or other sudden impact type loads. Devices such as snubbers, whip restraints, or spring supports are useful. These devices provide support while at the same time allowing movement (and in some cases control movement) due to thermal expansion and other sudden dynamic loads.

Piping installation - Care should be taken to prevent surface damage when installing piping. Piping should be erected level or with indicated slope. Installation tolerances must be meet specification.

When designing and installing piping systems it is important to carefully consider a means of support for the layout of a piping system. In doing so the layout and location of the pipes must be considers along with he design and layout of the building and equipment within the system. Piping should be routed so as to take advantage of surrounding structure and provide logical points of support, anchors, guides, or restraints with ample space for appropriate hardware.

There are numerous types of pipe supporting devices designed to support a piping system. The supporting devices used for a system must be designed to meet all static as well as dynamic operational conditions to which piping and equipment may be subjected. The support system must provide for and control movement caused by thermal expansion and contraction of the piping and connected equipment and potential dynamic movement caused by seismic events such as water hammer, steam hammer, or other sudden impact type loads.

When no movement is expected a **piping anchor** will be sufficient to secure a pipe. However is small amounts of movement are expected a pipe hanger or support would be necessary as a minimum. **Pipe hangers** are used to support and restrain long unsupported piping runs.

Anytime a significant amount of movement is expected due to thermal expansion or contraction spring supports are appropriate because they allow for a wider movement while still providing the necessary support for a piping system. In cases where dynamic loads may result due to seismic events or events such as water hammer, steam hammer, or other sudden impact type loads. Devices such as snubbers, whip restraints, or spring supports are useful. These devices provide support while at the same time allowing movement (and in some cases control movement) due to thermal expansion and other sudden dynamic loads.

Snubbers - are a type of specialized pipe support. When pipe loads undergo large rapidly varying loads the pipe snubbers lock-up and carry the load. Under small movements due to thermal expansion the snubbers are free to move to allow for the relatively slow expansion and contracts. Snubbers can work using mechanical or hydraulic action. Piping system must be analyzed for all loads acting on the pipe, including: thermal, seismic, and dynamic loads.

Piping insulation - is used to prevent the transfer of heat from piping fluid hotter than the surroundings or to piping that is cooler than the surroundings. Insulation is used to maintain desired temperatures in systems. Insulation also prevents damage or injury due to high temperature or low temperature fluids contained in the piping. Insulation is also installed to prevent condensation from forming on exposed piping. Insulation is specified by engineering on Piping & Instrumentation Diagrams. Care should be taken to prevent insulation from being wetted, once wetted insulation should be removed and replaced. Care should be taken to ensure proper type and thickness of insulation installed. The type of piping and temperature of contained fluid determines the type of insulation to be used. Insulation is to be properly installed and sealed. Exposure to asbestos (formerly used for insulation) has been identified as a source of cancer, special training is required. Do not handle asbestos material without special training.

Insulation must be considers for the piping system if required. It must first be determined if the insulation requirements are for system operation concerns of personnel safety or both. There are specific requirements for types of insulation that can be used in various situations and applications. Additionally there are requirements for thicknesses, spacing and clearance from one pipe to the next, components, walls, personnel access etc. It must also be noted that any time a pipe support of any kind is encountered it will probably require modification of the insulation.

Expansion joints - used in medium and high pressure and temperature piping to allow for the expansion and contraction of piping and components. Installed in piping at appropriate lengths to allow pipe movement when heated or cooled.

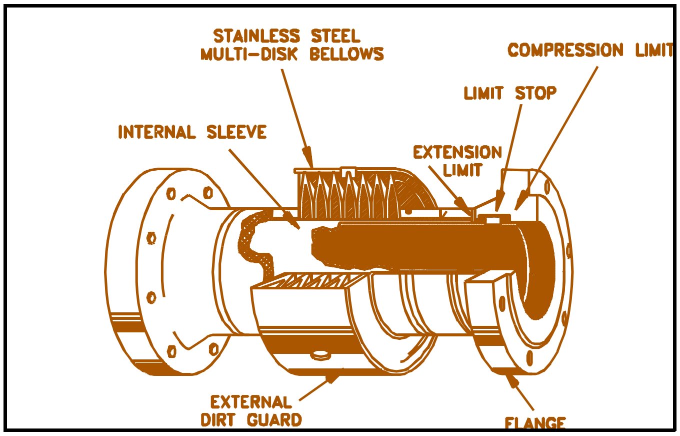


Figure 11 Expansion Joint

Piping connections -

Allows the joining of different length and size pipes to allow a flow path for fluids. Several different methods available dependent on system parameters (primarily pressure). Cost and need for disassembly of system also determine type of connector used. Connectors can be different types of fittings to allow versatility. Fittings can be tee, cross, elbow, bend, reducer, expander, nipple, or coupling.

Fitting - any component that changes direction, alters function, or simply makes end connections. Fittings are components designed to connect together pipe lines, valves, and other parts. Or fittings can be used to change pipe size or direction. May come as screwed, welded, soldered, or flanged. Fittings are specified by the nominal pipe size, type of material, and name of fitting.

Threaded - Simplest form of piping connector. Typically used on low pressure systems. Union fittings allow pipes to be connected (threaded or screwed together) for assembly or disassembly. Used for piping 2 inches in diameter or smaller.

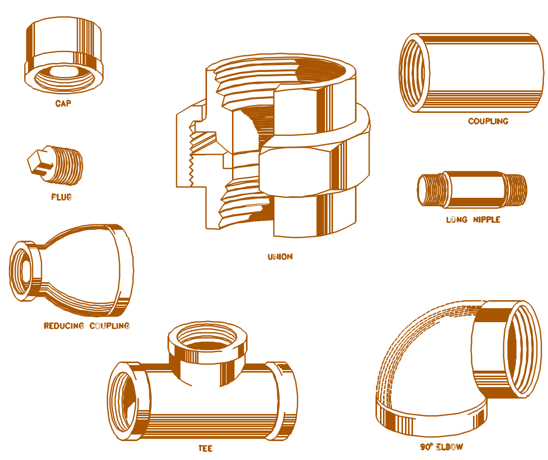


Figure 12 Threaded Piping Connections

Typically low temperature and low pressure applications. The fitting come machined and threaded with standard pipe threads. Threads can be straight thread or taper. In typically use a fitting is used with straight thread and the pipe uses tapered threads, to form tighter seals. Joints use pipe dope or compounds to form tight seals. Threaded seals connections are considered the least leak-proof. Threading the pipe or fitting removes some of the thickness of pipe, threaded connections are not used in high pressure applications. Cutting the thread on piping can remove up to 50% of thickness of the piping.

Flanged - Flanged (or bolted flange) suitable for all ranges of pressure. A flange is connected to the ends of the piping (welded or manufactured) and bolts or studs used to draw flanges together. Typically a gasket is used between the flanges to provide seating and sealing. Flanged used where frequent dismantling is required. Flanges also used where it is impossible to weld due to fire hazards. Typically flanges weight 3-4 times more than a welded or screwed connection. Flange connections requires a minimum two inch diameter pipe, typically cast steel or iron pipe. Cast steel used where pipe subject to shock or high temperature pressure situations as cast iron has tendency to crack. Flanges can be cast, forged, screwed, or welded onto pipe ends.

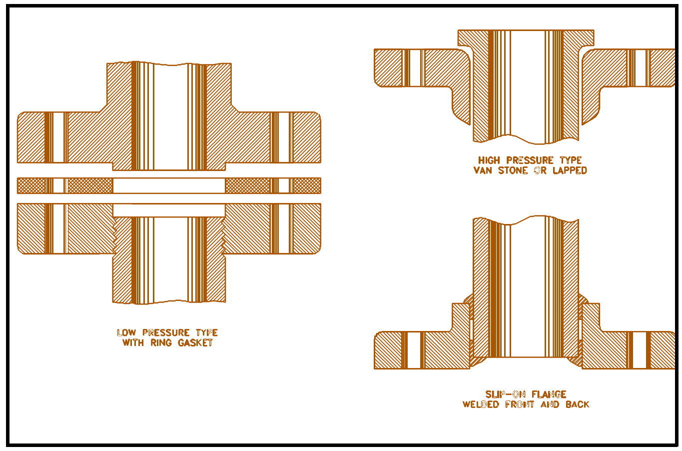


Figure 13 Flanged Piping Connections

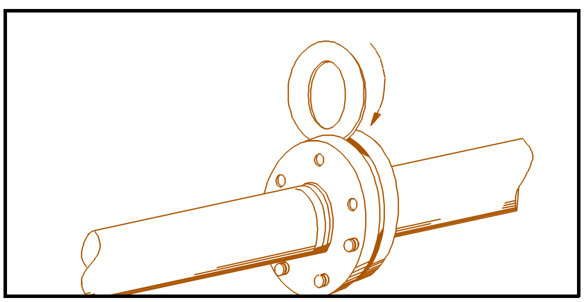


Figure 14 Inserting a Gasket Between Flanges

The advantage of flanged connections is the connections are easily assembled or disassembled. The disadvantage is that flanged connections are large, heavier, and occupy more space. Extremely important to increase supporting or hanging structures.

Socket - A type of brazed or welded piping connection. The pipe to be connected is inserted into a fitting and brazed or welded in place. The advantage of socket welded fittings is that it is easier use on small pipelines as the ends do not need to be beveled; the weld does not project into flow path, which minimizes headloss of the fluid; pipes are self aligning, no tack weld needed; low chance of leakage; less expensive. A disadvantage or problem with improperly aligned or mated socket welded fittings is that the pipe can form void or recess where erosion or corrosion (pitting and crevice corrosion) can occur.

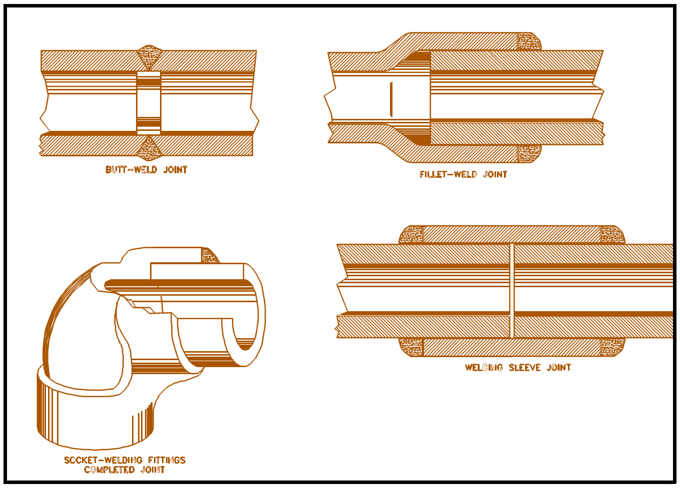


Figure 15 Welded Pipe Connections

Soldered fittings. Primarily used for brass or copper fittings and wrought metal, cast brass, or bronze piping. Soldered joints are typically ¼" to 4" in diameter, and are used in low temperature and low pressure applications.

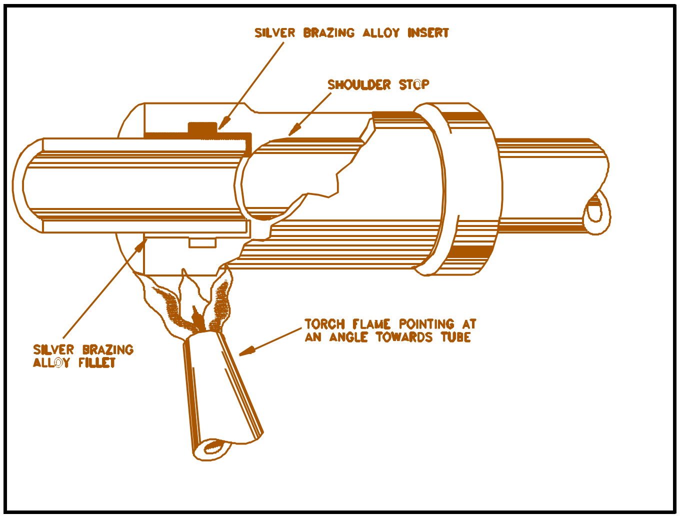


Figure 16 Brazed Piping Connection

Butt welded - Commonly used in high pressure applications. A type of welded piping connection. The pipe to be connected is matched up to another pipe or fitting and welded in place. Ends are machine grooved to form a bevel then fused together by welding. The advantage of welding over screwed or flanged connection is that welding requires less maintenance and is a permanent leak proof bond. Welded joints weigh less than flanged connections and do not require as much clearance. Screwed and flanged connections are larger and heavier. Welded joints fit closer to walls and ceiling. Welded joints are easier to insulate.

Welding used in more permanent applications. Advantages include: smooth inner wall surface which minimizes turbulence, friction, and headloss of the fluid in the piping; require less space to mount and hang; leak-proof connections; almost maintenance free; high temperature and pressure limits; self contained system; easy to insulate; and uniform wall thickness which ensures pressure boundary. The primary disadvantage of welded joints is that the joints are not easy to dismantle, welding limited to fairly permanent piping connections.

Compression joints - or pressure fitting. Typically used on small diameter, low pressure piping or tubing. Tubing is fitted with small compression ring and inserted into coupling or fitting. When compression fitting is tighten the ring provides a tight seal.

Flared fittings. Flared fittings are used on copper tubing for low pressure and low temperature applications.

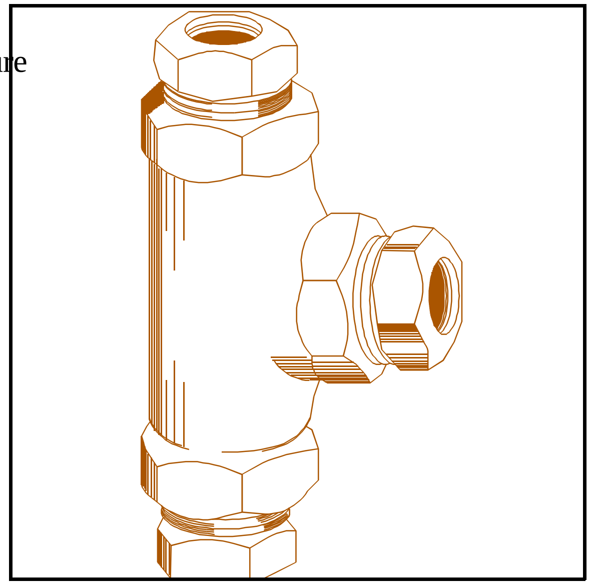


Figure 17 Compression Fitting Piping Connection

To change direction pipe can be bent. Bending stretches and thins wall of pipe. Flow resistance and erosion can cause damage to pipe. Thin wall also reduces pressure pipe an handle. Direction change can be done by single or double miter joint of straight lengths of pipe. Large increase in friction developed by this style direction change. An elbow fitting offers 6x less resistance than a single 90° miter bend. Therefore fitting are used more often to change direction of piping than bends or miter joints.

Figure 18 and Figure 19 illustrate symbols used to identify specific types of pipe fittings and connections.

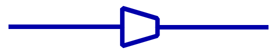
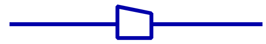
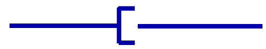
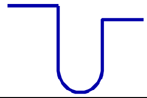
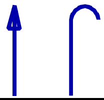
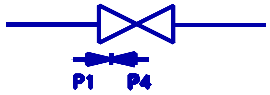
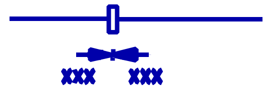
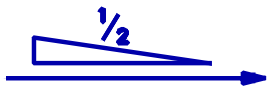
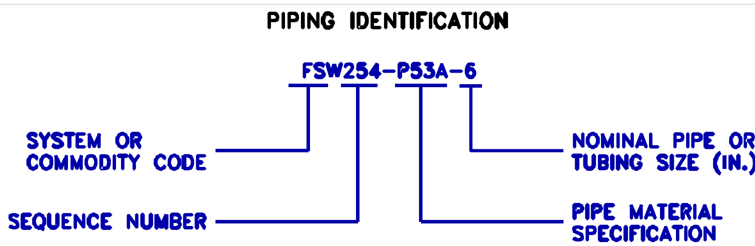
Figure 18 PIPING SYMBOLS			
Concentric reducer		Eccentric reducer	
Welded cap		Screw cap	
Hose cap		Quick disconnect	
Removable spool		Flexible connect	
Blind flange		Loop seal	
Funnel		Vent	

Figure 19 PIPING SYMBOLS			
Piping Change		Piping Change	
Slope		Dupont Valve Code	



Methods of installation of mechanical components

Pumps - May require limitation on suction pipe configuration and arrangement. Pumps have to be mounted to structural base, piping connections, and prime movers. Mounting must be performed to ensure alignment of pipes and that connections can be made.

When installing equipment consideration should be given to the location of the equipment. The area should allow accessibility for installing the equipment, routine operations, and maintenance. There should be adequate light for inspection. The layout of piping and cable runs should be as simple as possible. For pumps the height of lift required should be considered. Factors that affect the lift should also be considered: temperature, height above sea level, pipe friction, suction line fittings, foot valves, and strainer losses.

The foundation for mounting equipment serves as an important base. The foundation should be strong enough for permanent rigid support, which would allow it to absorb the normal strains and shocks the equipment would be expected to undergo. Typically the foundation bolts should be set in concrete. The steelwork should be supported above the main members and beams so that the base plate will not undergo distortion. Ensure enough room is left for grouting.

Once installed the equipment should be leveled, this can be accomplished by using steel plates and wedges. Ensure the pump shaft is level. It is critical that alignments of pump and driver be made to ensure the components lineup square and level. Typically the suction and discharge flanges are positioned to be vertical or horizontal. Ensure final alignments take in to consideration the expansion and contraction of normal operating temperatures and pressures. Finally the grout should be spread and allowed to dry. Once dry the downhold bolts should be tighten or torqued to specifications. The pump and driver coupling alignment should also be rechecked.

The inlet pipe of a pump should not be smaller than the pump inlet. The piping should be as short and as straight as possible. The number of elbows and bends should be reduced to minimize the losses due to friction. If the supply is the system lowpoint the suction pipe will remain submerged during pump operations. Strainers may be placed in the suction line to prevent foreign material from entering the pump or system. Care should be taken to ensure the strainer is properly sized to ensure: no object large enough to cause damage to the pump or system may bypass the strainer and that the strainer capacity will not starve the pump and cause cavitation.

The discharge pipe should be short and free from constriction. Typically, the discharge line is smaller than the inlet line. A common practice is to have the discharge line extend upward to prevent trapping gases in the pump casing. Installed check valves and gate valves should be as near the pump as possible. For positive displacement pumps, the relief valve should be as close as possible to the pump and not isolatable. The discharge of the relief valve should return to the pump suction or suction reservoir. For centrifugal pumps, a small recirculation line, from the pump discharge to the pump suction, should be installed to allow flow through the pump should the discharge valve close.

Heat exchangers - Heat exchangers have to be mounted to structural base and piping connections. Mounting must be performed to ensure alignment of pipes and include flexibility for thermal expansion and contraction.

Compressors - When evaluating the installation of a compressor the following should be considered. The compressor should be installed near the center of its load. A compressor however should not operate unsupervised. This supervision may be in the form of a person observing the operation or remote operation by instrumentation. The cost of each should be considered when determining the location for installation.

The compressor will give better service if it is located inside a building, especially if it is subject to be exposed to cold weather. In warmer climates a simple roof may be acceptable. Because they can be a large heat load it is important that the area they are located in be well ventilated. The ventilation ensures the air going into the compressor is not contaminated with exhaust from the motor and the motor will remain well cooled. And never place a compressor in an area that is dusty or damp.

Stationary compressors must be anchored to a solid mounting. The foundation must be stable enough to ensure the compressor and its driver remain in alignment, level, at the proper elevation, minimize vibration, and prevent vibration to adjacent buildings.

The intake must be fitted with appropriated filter to ensure air quality in the system. A relief system should be installed on the discharge side of the compressor to ensure there is no damage to the compressor or system due to over pressure condition.

HVAC UNITS - When evaluating the construction and installation of a HVAC system, there are a myriad of things to consider. In addition to the size of the facility, elements such as the type of facility for which the system is intended for use is also important, i.e., commercial facilities, public buildings, educational facilities, transportation, or manufacturing facilities. How much heat load will the HVAC units be required to produce to maintain the desired conditions? The next considerations after the size and use of the facilities are items such as number of damper valves to be installed, valves, flow measuring devices, flow balancers, etc.

As you can see the considerations are numerous and varied. Therefore it is important that you research the topic carefully when evaluating a HVAC system during construction and installation. ASHRE documents provide an extensive amount of information.

Measuring piping system parameters

Refer to the DOE Topical Area Study Guide for Instrumentation and Control (SR-TA-I&C-SSG-01) for more information.

Force beam differential pressure detector - Construction - a beam is placed between two opposed bellows. The beam is on a pivot, the other end of the beam is connected to a transducer. Operation - the difference in pressure between the two bellows moves the beam. The beam pivots and causes the transducer to produce an output.

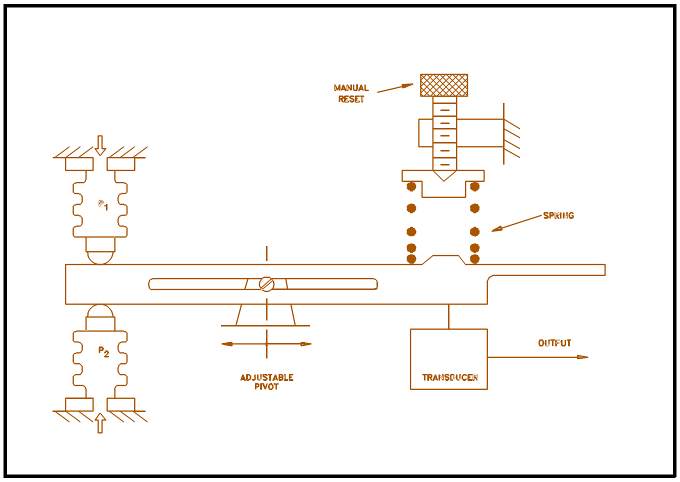


Figure 20 Force Beam Differential Pressure Gauge

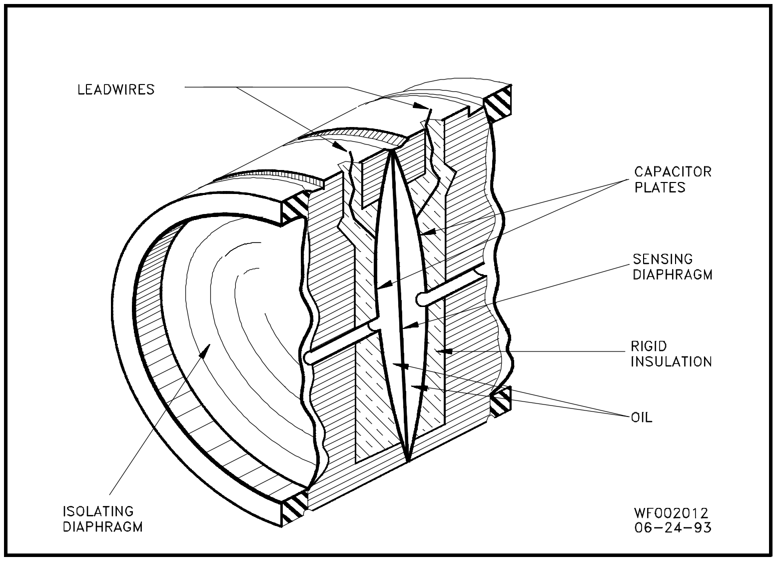


Figure 21 Capacitive-diaphragms pressure detector

Capacitive-diaphragm pressure detector
Construction - consists of a sensing diaphragm surrounded by a dielectric fluid and two isolating diaphragms. Operation - the difference in pressure between the two isolating diaphragms causes the dielectric fluid to move. This causes the sensing diaphragm to deflect. The deflection of the sensing diaphragm moves it closer to the capacitor plates changing the capacitance output of the detector.
The output is measure and converted to a pressure indication.

Manometer - used to detect and measure pressure. Construction - a U-shaped tube is partially filled with liquid. Each end of the tube is exposed to different pressures. Operation - the difference in the level of the fluid is used to determine the differences in pressure.

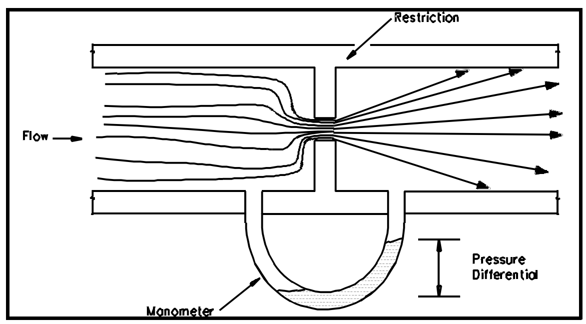


Figure 22 Head Flow Meter

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **1.1-B.1.a.** and **1.2-C.1.a.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Fluid Flow Level A Student Text (TTFGFF1A.H0100) Chapter Water Hammer Steam Hammer and Chapter Types of Flow.
   - Westinghouse Savannah River Company Engineering Requirements Document Number 15060-01-R, Process and Service Piping, Section 9.1.3.1 Maximum Test Pressure.

- Lamit, Louis Gary (1984). Pipe Fitting and Piping Handbook. Englewood Cliffs, NJ: Prentise-Hall. ISBN 0-13-676602-1. Chapter 1 Pipe Data
- Nayyar, Mohinder, P.E. (1992). Piping Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8. Part C, Water Systems Piping, Part D, Non-metallic Piping.
- Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications. Chapter Piping.
- Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 14 Fluid Lines and Fittings.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Piping, Valves, Gaskets, and Packing.

b. For Supporting Knowledge and Skills **1.1-B.1.b.** refer to:
   - Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications. Chapter Piping.
   - Lamit, Louis Gary (1984). Pipe Fitting and Piping Handbook. Englewood Cliffs, NJ: Prentise-Hall. ISBN 0-13-676602-1. Chapter 1 Pipe Data.
   - Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 14 Fluid Lines and Fittings.

c. For Supporting Knowledge and Skills **1.1-B.1.c.** refer to:
   - Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications. Chapter Piping.
   - Lamit, Louis Gary (1984). Pipe Fitting and Piping Handbook. Englewood Cliffs, NJ: Prentise-Hall. ISBN 0-13-676602-1. Chapter 1 Pipe Data.
   - Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 14 Fluid Lines and Fittings.
   - American Society of Mechanical Engineers (ASME) Code B31.1 Power Piping
   - American Society of Mechanical Engineers (ASME) Code ASME B31.3 - Chemical Plant and Petroleum Refinery Piping
   - American Society of Mechanical Engineers (ASME) Code ASME Building Services Piping

d. For Supporting Knowledge and Skills **1.1-B.1.d.**, **1.2-C.1.b.**, and **1.2-C.1.c.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Fluid Flow Level A Student Text (TTFGFF1A.H0100) Chapter Water Hammer Steam Hammer Pipe Whip.
- Westinghouse Savannah River Company High Level Waste Department Operator Training Program Applied Heat Transfer and Fluid Flow Study Guide (WGACFA06) Chapter Water Hammer.

e. For Supporting Knowledge and Skills **1.1-B.1.e.** and **1.2-C.1.d.** refer to:
- Nayyar, Mohinder L. P.E. (1992). Piping Handbook Sixth Edition. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8. Section B5 Piping Supports.

f. For Supporting Knowledge and Skills **1.1-B.1.f.** refer to:
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Piping, Valves, Gaskets, and Packing.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15020-01-R, Installation of Mechanical Equipment.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15060-01-R, Process and Service Piping.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15140-01-R, Field Fabrication and Installation of Pipe Supports.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15250-01-R, Mechanical Insulation.
- DOE Order 6430.1A General Design Criteria Division 15 Mechanical , Section 1525 Mechanical Insulation.
- Nayyar, Mohinder L. P.E. (1992). Piping Handbook Sixth Edition. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8. Section B3 Piping Layout, Section B5 Piping Supports, Section B7 Thermal Insulation of Piping.

g. For Supporting Knowledge and Skills **1.1-B.1.g.** and **1.2-C.1.f.** refer to:
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter 7 Piping, Valves, Gaskets, and Packing.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15020-01-R, Installation of Mechanical Equipment.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15060-01-R, Process and Service Piping.
- Westinghouse Savannah River Site Engineering Requirement Document No. 15140-01-R, Field Fabrication and Installation of Pipe Supports.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock

Ordering No. 0502-052-6210. Chapter Piping, Valves, Gaskets, and Packing.
- Bureau of Naval Personnel (Revised 1971). Fireman Rate Training Manual (NAVPERS 10520-D). Washington, DC: Training Publications Division. Stock Order No. 0500-137-1010. Chapter 10 Pumps, Valves, and Piping.
- Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications. Chapter Piping.

h. For Supporting Knowledge and Skills **1.1-B.1.h.** refer to:
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 3 Centrifugal Pumps; Chapter 4 Rotary Pumps; Chapter 5 Reciprocating Pumps.
- American Society of Mechanical Engineers, Boiler and Pressure Vessel Code (ASME BPVC).
- Westinghouse Savannah River Site Engineering Requirement Document No. M-SPC-G-00021, Generic Specification of Mechanical Equipment.
- American Society of Heating, Refrigeration and Air-conditioning Engineers (1993). ASHRAE Handbook Fundamentals. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers.
- American Society of Heating, Refrigeration and Air-conditioning Engineers (1990). ASHRAE Handbook Refrigeration Systems and Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers
- American Society of Heating, Refrigeration and Air-conditioning Engineers, (1991). ASHRAE Handbook HVAC Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers
- American Society of Heating, Refrigeration and Air-conditioning Engineers (1992). ASHRAE Handbook HVAC Systems and Equipment. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers
- Loomis A. W., (1982). Compressed Air and Gas Data. Washington, NJ: Ingersoll-Rand Company.

e. For Supporting Knowledge and Skills **1.2-C.1.e.** refer to:
- DOE Instrumentation and Control Topical Area Self-Study Guide SR-TA-I&C-SSG-01.
- Westinghouse Savannah River Company Core Fundamentals Training Program Instrumentation and Controls Student Text (TTFGIC1A.H0100) Chapter Temperature Measurement; Chapter Pressure Measurement.

4. Practice Exercise

   a. A normal piping run requires standard schedule piping what schedule number should be used? (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

      1) 1

      2) 10

      3) 20

      4) 40

   b. A 2-inch nominal standard schedule pipe is being compared to a 2-inch nominal extra strong schedule pipe. Which statement below is true? (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

      1) outside diameters are the same, the inside diameters are the same, and the pipe material is different.

      2) outside diameters are the different and the inside diameters are the same.

      3) outside diameters are the same and the inside diameters are the different.

      4) outside diameters are the different and the inside diameters are the different.

   c. A piping system is being designed to transport a liquid over a large distance, which type of fluid flow is desired? (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

      1) Venturi

      2) Turbulent

      3) Plastic

      4) Laminar

d. List four steps that can be taken to prevent water hammer from occurring in a steam pipe. (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

1)

2)

3)

4)

e. A fluid line ruptures and the pipe is being moved by reaction forces, this is called ________ . (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

1) pipe whip

2) pump action

3) resonance

4) water hammer

f. List two advantages and two disadvantages associated with plastic piping. (K&S 1.1-B.1.b.)

Advantages	Disadvantages

g. Which of the statements below describes the purposes of a snubber? (K&S 1.1-B.1.e.) (K&S 1.2-C.1.d.)

1) Allow movement under large dynamic loading, and dampen motion from thermal expansion.

2) Prevent all movement of piping or components.

3) Allow for thermal expansion and contraction of piping and components.

4) Prevent movement under large dynamic loading, while allowing movement under small thermal expansion.

h. Match the piping component purpose in column A with the piping component in column B. Use the column B answers one time only. Ignore any response in column B not identified in column A. (K&S 1.1-B.1.f.)

Column A	Column B
__ 1. Allows the pipe to grow or shrink and maintain the fluid contained.	a. Expansion joints
	b. Piping anchors
__ 2. Allows normal thermal expansion and contraction, prevent movement under large varying loads.	c. Pipe hangers
	d. Piping insulation
__ 3. Prevents the transfer of heat from piping fluid hotter than the surroundings or to piping that is cooler than the surroundings.	e. Snubbers
	f. Threaded joint
__ 4. Piping support that allows no movement.	

i. This type of joint is easy to take apart and put together, but is weakens the strength of the pipe (K&S 1.1-B.1.g.) (K&S 1.2-C.1.f.)

   1) Compression joints

   2) Flanged connections

   3) Socket welded connections

   4) Threaded connections

j. This type of joint is easy to take apart and put together, but is generally heavier and takes up more space. (K&S 1.1-B.1.g.) (K&S 1.2-C.1.f.)

   1) Butt welded connections

   2) Compression joints

   3) Flanged connections

   4) Socket welded connections

k. Which of the following devices is **NOT** used to measure system pressure. (K&S 1.2-C.1.e.)

   1) Bourdon tube

   2) Manometer

   3) Pitot tube

   4) Thermocouple

l. Describe the construction and operation of a thermocouple. (K&S 1.2-C.1.e.)

m. Match the detector in column A with the method of operation in column B. Use the column B answers one time only. Ignore any response in column B not identified in column A.

Column A	Column B
__ 1. Bourdon tube pressure gauge	a. Pressure is applied to two sensing diaphragms. The higher pressure over comes the lower pressure and the isolation diaphragm repositions changing the capacitance of the detector.
__ 2. Manometer	
__ 3. Pitot tube	b. Small hole in the end of a tube is positioned so that it faces the flowing fluid. The velocity of the fluid entering the opening of the tube decreases to zero and is converted into pressure.
	c. A one piece, collapsible, seamless metallic unit that has deep folds in thin walled material. The pressure to be measured is applied inside the bellows, as the pressure increases the bellows expands. As the bellow expands or collapses a transducer sense the change in pressure.
	d. A slightly flattened arc shaped tube. Pressure is applied inside the tube tends to restore original round cross section, causing tube to straighten out. Tube permanently fastened at one end, so the tip movement can be used to position a pointer.
	e. A U-shaped tube is partially filled with liquid. Each end of the tube is exposed to different pressures. The high pressure overcomes the low pressure and the liquid is move toward the low pressure side.

n. Temperature is being measured using a Resistance Temperature Detector (RTD). Complete the following descriptions. (K&S 1.2-C.1.e.)

1) The temperature the RTD is sensing is decreasing, the [capacitance] [resistance] [voltage] (select one) is [increasing] [decreasing] (select one).

2) A short occurs in the RTD leg, the indicated temperature is [failed low] [low] [high] [failed high]. (Select one.)

5. Practice Answers

   a. A normal piping run requires standard schedule piping what schedule number should be used? (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

      1) 1

      2) 10

      3) 20

      4) 40

   b. A 2-inch nominal standard schedule pipe is being compared to a 2-inch nominal extra strong schedule pipe. Which statement below is true? (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

      1) outside diameters are the same, the inside diameters are the same, and the pipe material is different.

      2) outside diameters are the different and the inside diameters are the same.

      3) outside diameters are the same and the inside diameters are the different.

      4) outside diameters are the different and the inside diameters are the different.

   c. A piping system is being designed to transport a liquid over a large distance, which type of fluid flow is desired? (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

      1) Venturi

      2) Turbulent

      3) Plastic

      4) Laminar

d. List four steps that can be taken to prevent water hammer from occurring in a steam pipe. (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

1) Ensure the steam line is properly drained before admitting flow
2) Warm up steam lines slowly
3) Ensure the steam trap bypass valves are open during system warmup
4) Ensure steam line insulation is properly installed
5) After steam line warm up, place steam traps in service and secure bypass valves
6) Ensure steam traps are operating correctly during normal operations
7) Ensure steam generator moisture separator or mist eliminators are operating
8) Minimize carryover from steam generators

e. A fluid line ruptures and the pipe is being moved by reaction forces, this is called ________ . (K&S 1.1-B.1.a.) (K&S 1.2-C.1.a.)

1) **pipe whip**
2) pump action
3) resonance
4) water hammer

f. List two advantages and two disadvantages associated with plastic piping. (K&S 1.1-B.1.b.)

Advantages	Disadvantages
Inexpensive. Easy to install. Resistant to chemical attack. Not effected by most hydraulics. Handles petroleum products and chlorinated hydrocarbons. Can be used as liners in high pressure low temperature pipe.	Exposure to sunlight weaken the piping Needs replacement For low temperature and pressure application only

g. Which of the statements below describes the purposes of a snubber? (K&S 1.1-B.1.e.) (K&S 1.2-C.1.d.)

1) Allow movement under large dynamic loading, and dampen motion from thermal expansion.

2) Prevent all movement of piping or components.

3) Allow for thermal expansion and contraction of piping and components.

4) Prevent movement under large dynamic loading, while allowing movement under small thermal expansion.

h. Match the piping component purpose in column A with the piping component in column B. Use the column B answers one time only. Ignore any response in column B not identified in column A. (K&S 1.1-B.1.f.)

Column A	Column B
_a_ 1. Allows the pipe to grow or shrink and maintain the fluid contained.	a. Expansion joints
	b. Piping anchors
_e_ 2. Allows normal thermal expansion and contraction, prevent movement under large varying loads.	c. Pipe hangers
	d. Piping insulation
_d_ 3. Prevents the transfer of heat from piping fluid hotter than the surroundings or to piping that is cooler than the surroundings.	e. Snubbers
	f. Threaded joint
_b_ 4. Piping support that allows no movement.	

i. This type of joint is easy to take apart and put together, but is weakens the strength of the pipe (K&S 1.1-B.1.g.) (K&S 1.2-C.1.f.)

   1) Compression joints

   2) Flanged connections

   3) Socket welded connections

   4) Threaded connections

j. This type of joint is easy to take apart and put together, but is generally heavier and takes up more space. (K&S 1.1-B.1.g.) (K&S 1.2-C.1.f.)

   1) Butt welded connections

   2) Compression joints

   3) Flanged connections

   4) Socket welded connections

k. Which of the following devices is **NOT** used to measure system pressure. (K&S 1.2-C.1.e.)

   1) Bourdon tube

   2) Manometer

   3) Pitot tube

   4) Thermocouple

l. Describe the construction and operation of a thermocouple. (K&S 1.2-C.1.e.)

   Two dissimilar wires joined at one end surrounded by an insulator and enclosed in a metal sheath. The other ends are connected to meter or measuring circuit.

   When the measuring junction is heated, the electrons flow from one metal to the other metal. This produces a voltage, the voltage produced is proportional to the temperature sensed.

m. Match the detector in column A with the method of operation in column B. Use the column B answers one time only. Ignore any response in column B not identified in column A.

Column A	Column B
_d_ 1. Bourdon tube pressure gauge	a. Pressure is applied to two sensing diaphragms. The higher pressure over comes the lower pressure and the isolation diaphragm repositions changing the capacitance of the detector.
_e_ 2. Manometer	
_b_ 3. Pitot tube	b. Small hole in the end of a tube is positioned so that it faces the flowing fluid. The velocity of the fluid entering the opening of the tube decreases to zero and is converted into pressure.
	c. A one piece, collapsible, seamless metallic unit that has deep folds in thin walled material. The pressure to be measured is applied inside the bellows, as the pressure increases the bellows expands. As the bellow expands or collapses a transducer sense the change in pressure.
	d. A slightly flattened arc shaped tube. Pressure is applied inside the tube tends to restore original round cross section, causing tube to straighten out. Tube permanently fastened at one end, so the tip movement can be used to position a pointer.
	e. A U-shaped tube is partially filled with liquid. Each end of the tube is exposed to different pressures. The high pressure overcomes the low pressure and the liquid is move toward the low pressure side.

n. Temperature is being measured using a Resistance Temperature Detector (RTD). Complete the following descriptions. (K&S 1.2-C.1.e.)

1) The temperature the RTD is sensing is decreasing, the [capacitance] **[resistance]** [voltage] (select one) is [increasing] **[decreasing]** (select one).

2) A short occurs in the RTD leg, the indicated temperature is [failed low] [low] [high] **[failed high]**. (Select one.)

D. **Competency 1.3**

Construction management and engineering (FAC# 1.24), EH Residents (FAC# 1.5), Facility maintenance management (FAC# 1.2), Facility Representatives (FAC# 1.5), and Instrumentation and control (FAC# 1.17) personnel shall demonstrate a familiarity level knowledge of valve construction, operations, and theory.

1. Supporting Knowledge and Skills

   a. Describe the four basic types of flow control elements employed in valve design.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93), Volume 2 of 2, Module 4, Chapter Valves, page 6.

   b. Define the following terms as they relate to valves:

      - Disc
      - Seat
      - Body
      - Bonnet
      - Stem
      - Actuator
      - Packing
      - Bridgewall mark
      - Throttle

        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93), Volume 2 of 2, Module 4, Chapter Valves.

   c. Given a drawing of a valve, identify the major component parts.

      - Disc
      - Seat
      - Body
      - Bonnet
      - Stem
      - Actuator
      - Packing

        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 2, 4, and 5.

d. Describe the basic construction and operation of the following types of valves used in a process system:

- Gate valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 8-14.
- Globe valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 15-18.
- Flow control valve
- Ball valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 18-20.
- Butterfly valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 31-33.
- Diaphragm valves
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 24-28.
- Check valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 35-40.
- Regulating/reducing valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 28-30.
- Relief and safety valves
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 40-42.

e. Given a drawing of a valve, describe its normal design application in a piping system and identify which of the following general types of valve it is:

- Gate valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 8-14.
- Globe valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 15-18.
- Flow control valve
- Ball valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 18-20.

- Butterfly valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 31-33.
- Diaphragm valves
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 24-28.
- Check valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 35-40.
- Regulating/reducing valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 28-30.
- Relief and safety valves
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 40-42.

f. Given a diagram of a globe valve body showing the bridgewall mark, identify how the valve must be oriented in the system related to flow.

g. Describe the types of valves that are used to throttle flow.
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 15-18.

h. Discuss why gate valves, ball valves, and butterfly valves should never be used to throttle flow.
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 10.

i. Describe the construction and principle of operation for the following types of valve actuators used to control valve position:

- Manual
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 44-45.
- Electric motor
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 46.
- Solenoid
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 48-49.

- Pneumatic
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 47.
- Hydraulic
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 47.

j. Describe the basic operation of pressure regulating, temperature control, and flow control valves in a process system.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 28-30.

k. Define the following terms as they apply to safety and relief valves:

- Set point
- Blowdown
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 40.
- Accumulation
- Pilot-actuated
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 42.

l. Describe the purpose, operation and typical application of safety and relief valves.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 40-42.

m. Discuss how valve operation controlled by a process control system can cause water hammer or pressure spiking if the system is not designed properly.
   DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Chapter Two-Phase Fluid Flow.

E. **Competency 1.4**

Mechanical systems (FAC# 1.3 & 1.9) personnel shall demonstrate a working level knowledge of the general construction, operation, and theory of valves.

1. Supporting Knowledge and Skills

   a. Define the following terms as they relate to valves:

   - Disc
   - Seat
   - Body
   - Bonnet
   - Stem
   - Actuator
   - Packing
   - Bridgewall mark
   - Throttle

     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves.

   b. Using a drawing of a valve, identify which of the following general types of valve it is and, describe its normal design application in a piping system:

   - Gate valve

     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 8-14.
   - Globe valve

     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 15-18.
   - Flow control valve
   - Ball valve

     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 18-20.
   - Butterfly valve

     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 31-33.
   - Diaphragm valves

     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 24-28.

- Check valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 35-40.
- Regulating/reducing valve
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 28-30.
- Relief and safety valves
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 40-42.

c. Discuss why the design of a globe valve enables it to throttle fluids efficiently.

d. Using a diagram of a globe valve body showing the bridgewall mark, identify how the valve must be oriented in the system related to flow.

e. Discuss why gate valves, ball valves, and butterfly valves should never be used to throttle flow.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 8-14.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 18-20.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 31-33.

f. Discuss how cavitation occurs in valves and state any harmful effects that can result from cavitation.

g. Describe the construction and principle of operation for the following types of valve actuators:

- Manual
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 44-45.
- Electric motor
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 46.
- Solenoid
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 48-49.
- Pneumatic
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 47.

- Hydraulic
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valve Actuators, page 47.

h. Describe the principles of operation and applications for modulating and pressure reducing valves.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 28-30.

i. Define the following terms as they pertain to safety and relief valves:

- Set point
- Accumulation
- Blowdown
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 40.
- Pilot-actuated
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 42.

j. Compare and contrast the purpose and operation of safety and relief valves.
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 40-42.

k. Discuss how blowdown and accumulation are controlled in safety and relief valves.

l. Using a cutaway drawing of a safety valve, identify the main components to include:

- Seat
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 42.
- Disc
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 42.
- Blowdown ring
- Main spring
- Set-point adjustment mechanism
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 4, Chapter Valves, page 42.

m. Discuss the methods used to test relief valves.

2. Self-Study Information

Competency 1.3 and 1.4 address valve construction, theory, and purpose. Competency 1.3 at a familiarity level and Competency 1.4 at a working level of knowledge.

The supporting material for the Self-Study Activities include the following documents:

- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2
- Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 106
- American National Standards Institute/ American Society of Mechanical Engineers ANSI/ASME OM-1 Requirements for Inservice Performance Testing of Nuclear Power Plant Pressure Relief Devices
- Brumbaugh, James E. (1983). <u>Heating, Ventilating and Air Conditioning Library Volume 2</u>. Indianapolis, IN: Bobbs Merrill Company, Inc. ISBN 0-672-23382-7.
- Considine, Douglas M., P.E. (1993). <u>Process/Industrial Instruments & Control Handbook</u>. New York, NY: McGraw-Hill, Inc. ISBN 0-07-012445-0.
- Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.
- Nayyar, Mohinder, P.E. (1992). <u>Piping Handbook</u>. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8.
- Schweitzer, Philip A. (1972). <u>Handbook of Valves</u>. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39.
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100)
- Westinghouse Savannah River Company High Level Waste Operator Training Heat Transfer and Fluid Flow Study Guide (NWMOG009.H0103)

Basic Valve Construction

There are many valve designs that satisfy one or more of the functions previously listed (each of the major valve designs will be discussed later). Regardless of the particular valve design, they all have the same five basic parts:

- Body
- Bonnet
- Trim of a valve represents the replaceable parts of valve where majority of wear occurs. Typically consisting of the stem, seat ring, wedge, disc, and packing.
- Actuator
- Packing

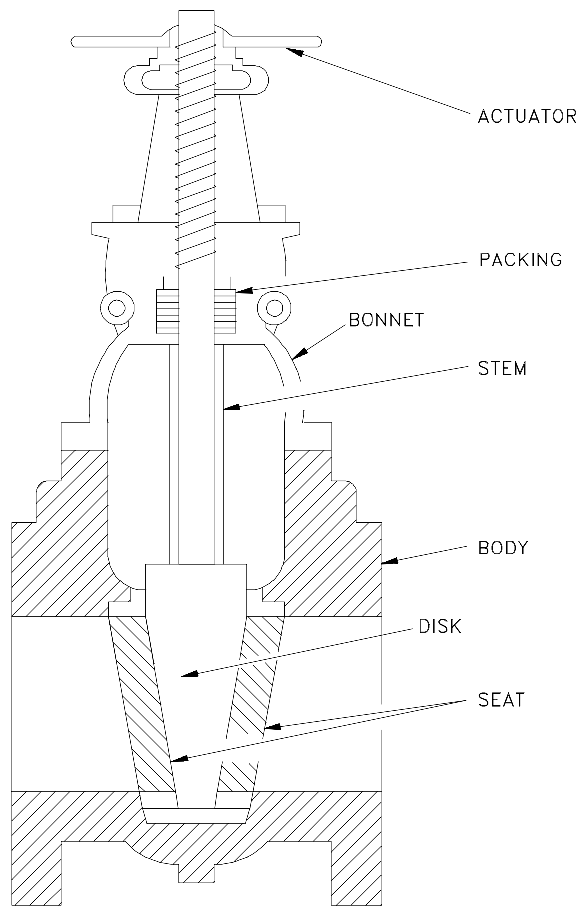


Figure 23 Basic Valve Parts

Types of Valves

Because of the diversity of the types of systems, fluids, and environments in which valves must operate, a variety of valve types have been developed. Each type of valve has been designed to meet specific needs. Each valve type has certain inherent advantages and disadvantages. We need to understand these differences and how they affect the valve's application or operation.

All valves have the same basic components. All valves can function to control flow. However, the method of controlling the flow can vary widely. In general, there are four methods of controlling flow through a valve.

1. Slide a flat, cylindrical surface across an orifice (gate valves).

2. Move a disc or plug into or against an orifice (globe and needle valves).

3. Rotate a disc, sphere, or ellipse about a shaft extending across the diameter of an orifice (butterfly, ball, or plug valves).

4. Move a flexible material into the flow passage (diaphragm and pinch valves).

All valves can be used to start and stop flow. Some isolate flow more completely than others, and some can also be used to vary the flow rate in a system. Each method of controlling flow has characteristics that make it the best choice for a given application or function. No valve is the best for all applications. As a result, we find many different variations of each valve type, as well as "hybrids" of two different valve types.

Throttling - to reduce the flow by means of a valve used to regulate. To place a valve in a mid-position so that so flow is allowed but the valve is not full open or full closed.

Globe valves. There is a *right* way and a *wrong* way to install a globe valve. The outside of the valve body usually has either an arrow showing the correct flow direction or a "bridgewall" marking which is a schematic picture of the valve is internal construction. We can use either of these methods to verify the correct installation of a globe valve. An incorrectly installed globe valve will not perform as designed and may become unsafe.

Normally globe valve installed with pressure under disc. This provides two benefits. First it provide protection to disc and seat, when the valve is closed fluid is below the disc so any particulate will settle out below the disc not above the disc where they might build and wear away the disc and seat when the valve is opened. Secondly, although not typically performed in high pressure and hazardous fluid systems, this allows the packing to be replaced with valve in service. One application where the pressure is applied above the disc is in steam lines installed when the steam pressure is applied above the disc. If the steam was applied below disc and the valve closed, the stem may cool and contract. The cooling and contracting stem would in turn lift the disc off the seat, this would allow steam to flow through valve which is supposed to be closed.

The globe valve disk can be totally withdrawn from the flowpath or can completely block the flowpath. The essential principle of globe valve operation is the perpendicular movement of the disk away from the seat. The size of the space between the disk and seat is proportional to the amount of flow allowed to pass and is controlled by positioning the disk with the valve actuator. This characteristic gives the globe valve good throttling ability. This allows globe valves to be used effectively to control system flow. The globe valve is effective for both flow isolation and flow regulation.

Recall from Fluid Flow:

$pe_1 + ke_1 + u_1 + fe_1 + q_{in} + w_{in} = pe_2 + ke_2 + u_2 + fe_2 + q_{out} + w_{out}$

Consider a horizontal valve:

$pe_1 = pe_2$

Consider the inlet and outlet of the valve the same size:

$ke_1 = ke_2$

Assumption no heat transfer in or out of valve:

$q_{in} = q_{out}$

Assumption no work done by valve on fluid or by fluid on valve:

$w_{in} = w_{out}$

Assumption incompressible fluid:

$\nu_1 = \nu_2$

Therefore the equation simplifies down to:

$u_1 + fe_1 = u_2 + fe_2$

Values at point one are known and therefore constant. Turbulence in the valve causes an increase in the friction. The increase in the friction causes an increase in the internal energy in the specific internal energy at point two. Since energy can neither be created nor destroyed (Law of Conservation of Energy), the energy must come from some other energy form. In this case the only form of energy remaining to be changed is the specific flow energy must decrease. It can be said that the specific flow energy is being converted to specific internal energy.

$$\overset{\leftrightarrow}{u_1} + \overset{\leftrightarrow}{fe_1} = \overset{\uparrow}{u_2} + \overset{\downarrow}{fe_2}$$

-OR-

$fe \rightarrow u$

Since $fe = p\nu$

$u_1 + p\nu_1 = u_2 + p\nu_2$

Recall that specific flow energy is made up of pressure times specific volume. Because the fluid is an incompressible fluid, the specific volume remains constant. Therefore a decrease in the specific flow energy results in a decrease in the pressure.

$$\overset{\leftrightarrow}{u_1} + \overset{\leftrightarrow}{p\nu_1} = \overset{\uparrow}{u_2} + \overset{\downarrow\leftrightarrow}{p\nu_2}$$

Since pressure serves as the driving force of a fluid through a system, if the pressure decreases then the flow through the system must also decrease.

Flow control valves - are not a type of valve but rather an application of a valve. A valve serving as a flow control valve is an effective throttle valve. Globe valves and diaphragm valves are commonly used for flow control valve applications. The actuator of a flow control valve positions the stem and disk to allow the desired flow through the valve.

The basic operation of pressure regulating, temperature control flow control valves in a process system can take place in a number of different ways. First, whatever parameter is to be controlled must be measured. If the parameter is not within the given setpoints then a signal is sent to one of these valves to correct the parameter to within its preset limits. These valves are controlled by pneumatics, analog electronic control, or distributed digital control.

Water hammer is a liquid shock wave resulting from the sudden starting or stopping of flow. It is affected by the initial system pressure, the density of the fluid, the speed of sound in the fluid, the elasticity of the fluid and pipe, the change in velocity of the fluid, the diameter and thickness of the pipe, and the valve operating time.

Water hammer from improper valve operation can occur if an closed valve is open to rapidly (see Figure 24) or if an open valve is closed to rapidly (see Figure 25). If upstream of the valve is under high pressure or taps off a high flow line and downstream of the valve is empty

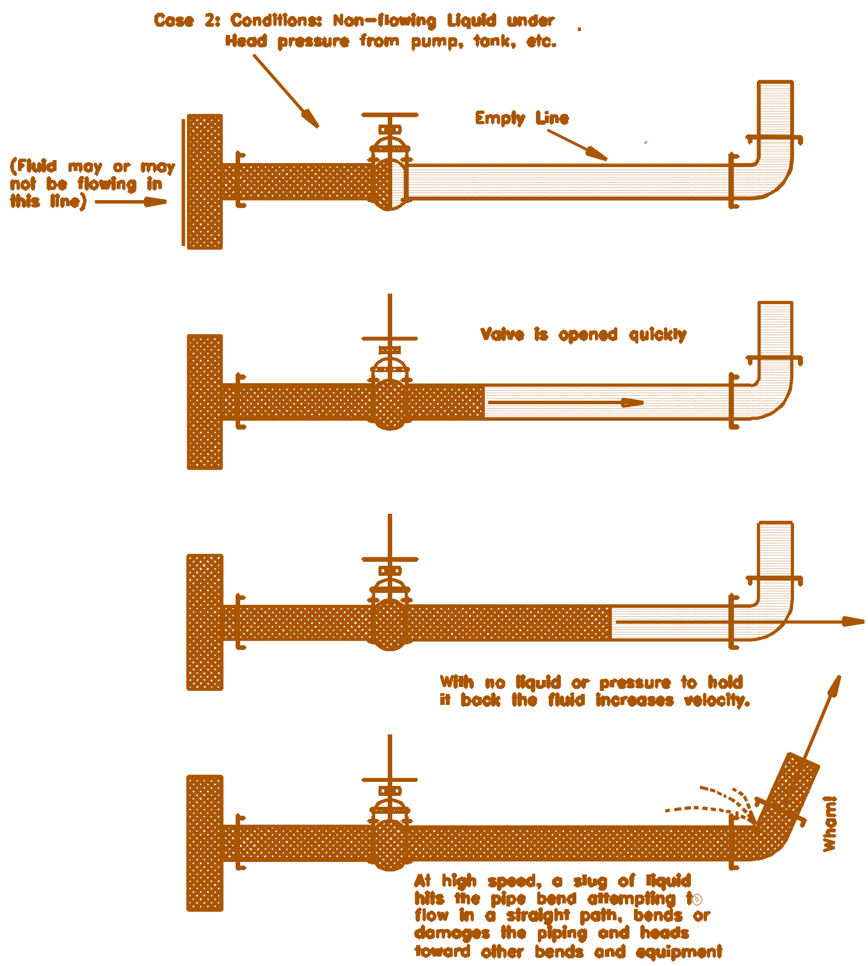


Figure 24 Water Hammer in Low Pressure Piping

or depressurized and the valve is rapidly open, the fast moving fluid travels unhindered down the empty pipe. The fluid moves at high velocity until there is an obstruction in the piping or the piping has a change in direction. The rapidly moving fluid (generally more of a problem if

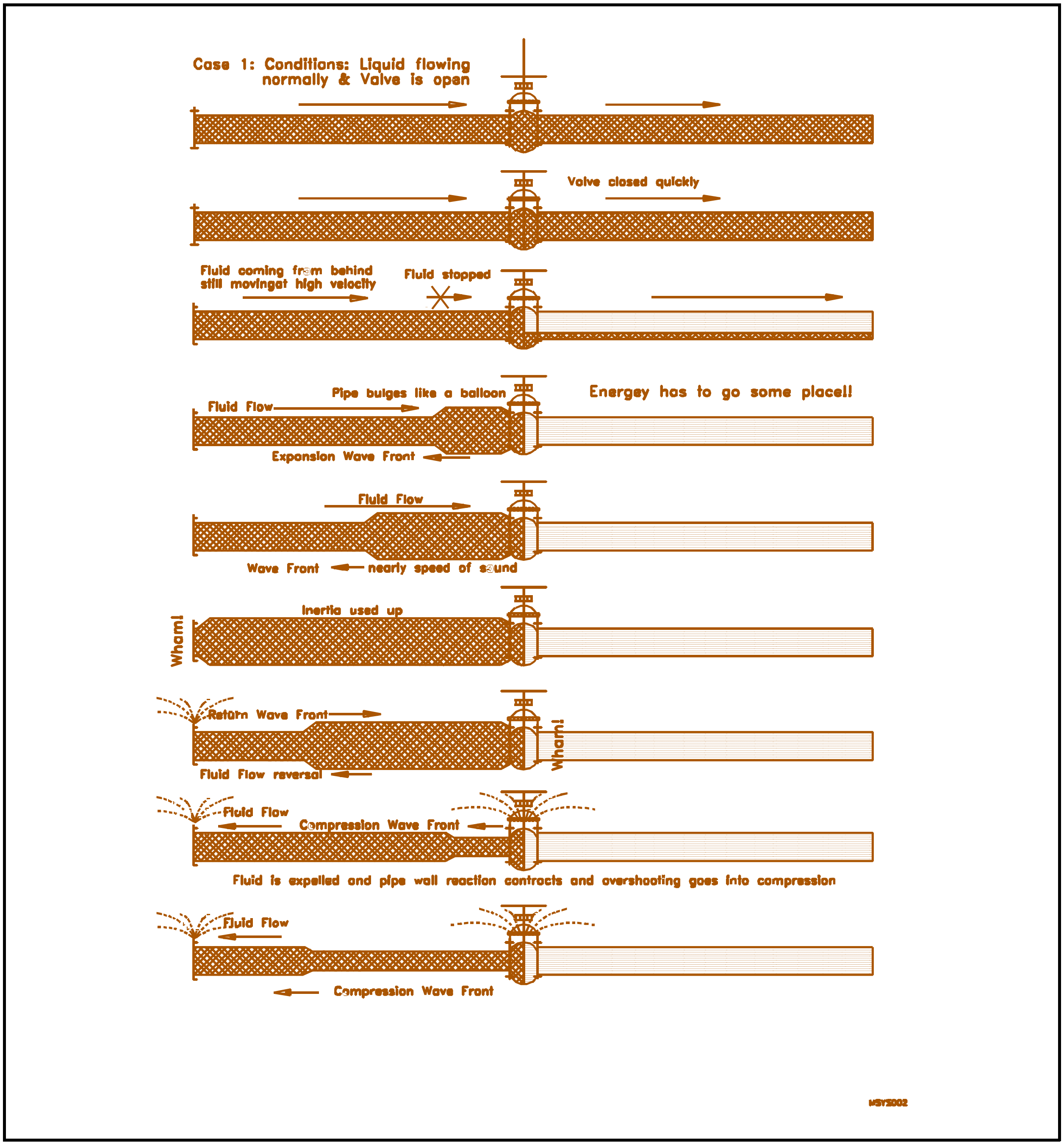


Figure 25 Valve Closure Induced Water Hammer

the fluid is a liquid) strikes the obstruction or pipe wall with a large amount of kinetic energy. When the fluid strikes the object the fluid rapidly comes to a stop. The kinetic energy of the fluid is transformed in to flow energy or pressure. The pressure exerts force on the object or wall, causing it to move or rupture.

During the closing of a valve, kinetic energy of the moving fluid is converted into flow energy (specifically pressure). Elasticity of the fluid and pipe wall produces a wave of positive pressure back toward the fluid's source. When this wave reaches the source, the mass of fluid will be at rest, but under tremendous pressure. The compressed liquid and stretched pipe walls will now start to release the liquid in the pipe back to the source and return to the static pressure of the source. This release of energy will form another pressure wave back to the valve. When this shockwave reaches the valve, due to the momentum of the fluid, the pipe wall will begin to contract. This contraction is transmitted back to the source, which places the pressure in the piping below that of the static pressure of the source. These pressure waves will travel back and forth several times until the fluid friction dampens the alternating pressure waves to the static pressure of the source. Normally, the entire hammer process takes place in under one second.

The initial shock of suddenly stopped flow can induce transient pressure changes that exceed the static pressure. If the valve is closed slowly, the loss of kinetic energy is gradual. If it is closed quickly, the loss of kinetic energy is very rapid. A shock wave results because of this rapid loss of kinetic energy. The shock wave caused by water hammer can be of sufficient magnitude to cause physical damage to piping, equipment, and personnel. Water hammer in pipes has been known to pull pipe supports from their mounts, rupture piping, and cause pipe whip.

Valves actuators are sized to operate the valve without causing water hammer. Operators should take care when opening or closing valves so that the operation does not cause water hammer. For manual handwheels operators should not spin open or closed valves. **Do not** use handwheels or actuators not designed for the valve.

Pressure Spike - is the resulting rapid rise in pressure above static pressure caused by water hammer. The highest pressure spike attained will be at the instant the flow changed and is governed by the following equation.

$$\Delta P = \frac{\rho_c \, \Delta v}{g_c}$$

where:

ΔP = Pressure spike $\left(\frac{lbf}{ft^2}\right)$

ρ = Density of the fluid $\left(\frac{lbm}{ft^3}\right)$

c = Velocity of the pressure wave (Speed of sound in the fluid) $\left(\frac{ft}{sec}\right)$

Δv = Change in velocity of the fluid $\left(\frac{ft}{sec}\right)$

g_c = Gravitational constant $32.17 \left(\frac{lbm-ft}{lbf-sec^2}\right)$

Example: Pressure spike

Water at a density of 62.4 lbm/ft^3 and a pressure of 120 psi is flowing through a pipe at 10 ft/sec. The speed of sound in the water is 4780 ft/sec. A check valve suddenly closed. What is the maximum pressure of the fluid in psi?

Solution:

$$P_{Max} = P_{Static} + \Delta P_{Spike}$$

$$P_{Max} = 120\,\frac{\text{lbf}}{\text{in}^2} + \frac{\rho_c\ \Delta V}{g_c}$$

$$P_{Max} = 120\,\frac{\text{lbf}}{\text{in}^2} + \frac{62.4\,\frac{\text{lbm}}{\text{ft}^3}\ \ 4780\,\frac{\text{ft}}{\text{sec}}\ \ 10\,\frac{\text{ft}}{\text{sec}}}{32.17\ \frac{\text{lbm ft}}{\text{lbf sec}^2}}$$

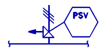
$$P_{Max} = 120\,\frac{\text{lbf}}{\text{in}^2} + 92{,}631\,\frac{\text{lbf}}{\text{ft}^2}\left(\frac{\text{ft}^2}{144\ \text{in}^2}\right)$$

$$P_{Max} = 120\,\frac{\text{lbf}}{\text{in}^2} + 643.3\,\frac{\text{lbf}}{\text{in}^2}$$

$$P_{Max} = 763.3 \text{ psi}$$

<u>Cavitation in valves</u>

Cavitation is normally associated with pumps but can occur in a valves. Cavitation is the formation of vapor bubbles in the low pressure region and subsequent collapse in high pressure regions. When a fluid that is close to its saturation temperature and pressure flows through a valve, a potential occurs that in the low pressure region of the valve some of the liquid will flash to a vapor. Then as the liquid exits the valve the energy conversions will increase the pressure of the fluid. The increase in pressure will cause the vapor to condense back to a liquid. The shock waves that develop from the collapsing bubbles can cause damage to the disc, seat, stem, and exit region of the body.

Relief and Safety Valves 

Relief valves and safety valves prevent equipment damage by relieving accidental over-pressurization of fluid systems. The main difference between a relief valve and a safety valve is the details of how they operate at the setpoint pressure.

A relief valve gradually opens as the inlet pressure increases above the setpoint and it only opens as much as necessary to relieve the over-pressure condition. A relief valve begins to open at the setpoint pressure, but it does not fully open immediately. The pressure must increase above the setpoint to make the valve open fully. The difference between the setpoint pressure and the pressure which fully opens the valve is called accumulation. That is,

$$\text{Accumulation} = p_{\text{full open}} - p_{\text{setpoint}}$$

The accumulation of a relief valve is usually a few psi.

A safety valve, on the other hand, rapidly pops fully open as soon as its pressure setpoint is reached. It will remain fully open until the pressure drops the reset point. The reset pressure is a lower pressure than the set pressure. The difference between the set pressure and the reset pressure is called blowdown. Blowdown is usually expressed as a percentage of the actuating pressure setpoint. That is,

$$\%\text{Blowdown} = \frac{p_{\text{set}} - p_{\text{reset}}}{p_{\text{set}}} \times 100\%$$

The basic operation of both the relief valve and safety valves is illustrated in Figure 26 and Figure 27. System pressure provides a force that is attempting to push the valve disk off its seat. Spring pressure on the stem is forcing the disk onto the seat. At the pressure determined by spring compression, system pressure overcomes spring pressure and the valve opens.

The valve will close after system pressure is relieved and the spring pressure again over-comes system pressure.

The pressure setpoints of these valves are adjusted by turning the adjusting nuts on top of the yoke to increase or decrease the spring compression.

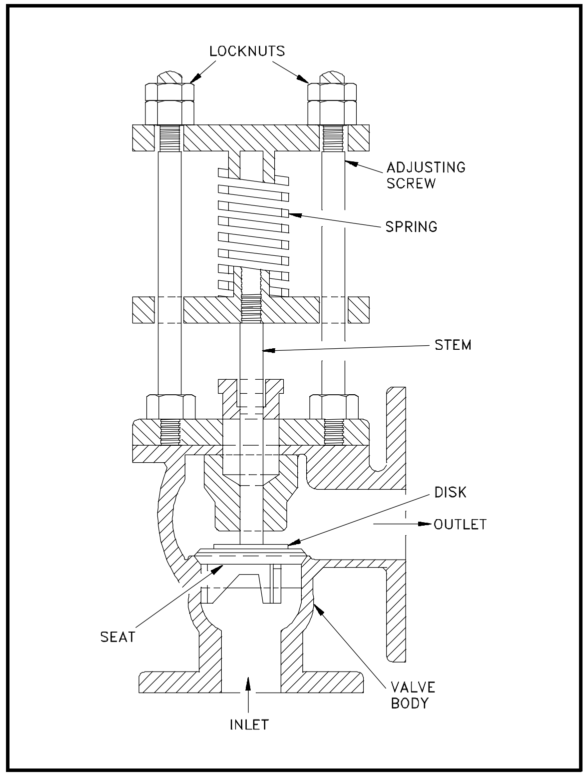


Figure 26 Relief Valve

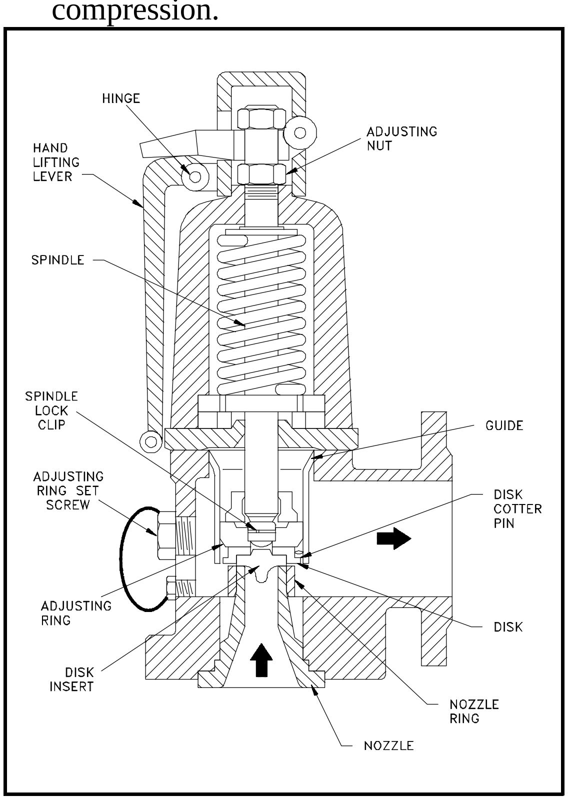


Figure 27 Safety Valve

R-elief valves are typically used for incompressible fluids such as water or oil. Safety valves are typically used for compressible fluids such as steam or other gases. Safety valves can often be distinguished by the presence of an external lever at the top of the valve body, which is used as an operational check. The advantage of a relief valve is that it will open only enough to relieve the pressure above the setpoint, therefore excess fluid will not be lost. The advantage of a safety valve is that the valve will open and remain open until the pressure is below the reset point, this ensures the pressure in the system has been significantly reduced.

Testing Relief Valves

Relief valves will be found on many different types of systems and components in any facility. Specific instructions of the settings and tolerances for each relief valve will be unique to the type valve, Manufacturer, system it operates on, and operating parameters. It is important that the proper settings are identified for the valve being tested. However there are general guidelines that exist for the parameters that should be tested and operating characteristics that they must display.

Generally, all safety relief valves should undergo the following:

1. Visual Examination
2. Seat tightness determination
3. Set pressure determination
4. Determination of compliance with Owner's seat tightness criteria
5. Determination of electrical characteristics and pressure integrity of solenoid valves
6. Determination of pressure integrity and stroke capability of air actuators
7. Determination of operation and electrical characteristics of position indicators
8. Determination of operation and electrical characteristics of bellows alarm switch
9. Determination of actuating pressure of auxiliary actuating device sensing element, where applicable

All of these may not be applicable to every valve but it does provide a generic list of potential tests. When performing the tests specific consideration must be given to the following:

1. Test media used.
2. Accumulator Volume
3. Assisting Devices used
4. Temperature stability
5. Ambient Temperature
6. Superimposed Back Pressure.
7. Control Rings
8. Time between Valve Openings
9. Number of tests to be performed

Each of these items to consider will vary depended on the type of system and media in the system being tested. Each of the above parameters are address for Steam systems, Compressible fluid services other than steam and Liquid Services.

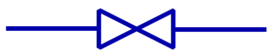
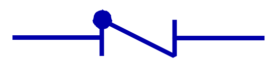
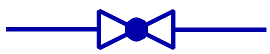
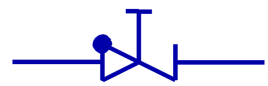
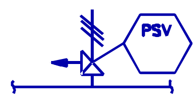
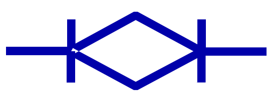
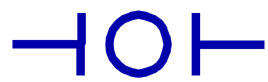
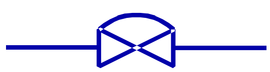
ANSI/ASME OM-1 Requirements for Inservice Performance Testing of Nuclear Power Plant Pressure Relief Devices provides specific instructions for the tests that must be performed on various types of pressure relief valves and the methods for testing them. It also include information on the acceptance criteria and required records for documentation.

Valve Symbols

Valves are used to control the direction, flow rate, and pressure of fluids. Figure 60 illustrates the major types of valves used in P&ID's. Figure 28 shows the symbols that depict major valve types and other flow control devices used at DOE facilities.

Different symbols are used to represent individual valve types. This is necessary because of the different ways each valve type affects system operation. On an actual P&ID, individual valves will be further identified by a specific valve number.

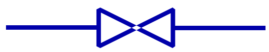
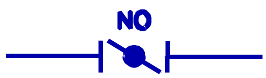
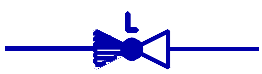
Figure 28 VALVE SYMBOLS

Gate valve		Check valve	
Globe valve		Stop check valve	
Needle valve		Safety valve	
Plug valve		Ball valve	
Diaphragm valve		Butterfly valve	

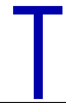
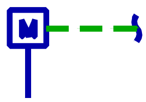
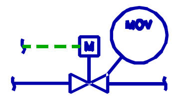
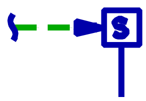
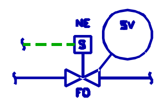
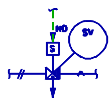
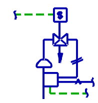
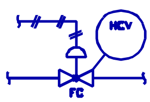
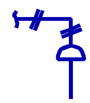
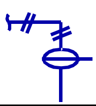
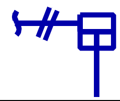
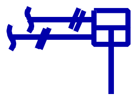
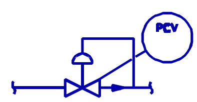
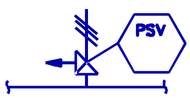
Standards and Conventions for Valve Status

Before a P&ID can be properly interpreted, the basic conventions used to denote valve status and failure modes must be understood. Figure 29 illustrates the symbols used. Unless otherwise stated, P&IDs indicate valves in their "normal" positions. This is usually interpreted as the normal or primary flowpath for the system. An exception is safety systems, which are normally shown in their standby or non-accident condition.

Figure 29 VALVE POSITION AND STATUS

Open (Gate) valve		Closed (Gate) valve	
Lock open (Gate) valve		Lock closed (Gate) valve	
Normally open (Butterfly) valve		Normally closed (Butterfly) valve	
Throttled and locked (Globe) valve			

Valve operators are used to allow the remote operation of valves. Figure 30 shows the symbols for common valve operators. If no valve operator symbol is shown, it may be assumed that the valve is equipped with only a handwheel for manual operation.

Figure 30 VALVE ACTUATORS			
Unclassified actuator		Hand actuator	
Rotary motor		Motor operated 2-way globe valve	
Single solenoid		Single solenoid 2-way valve normally energized (fail open)	
3-way Pilot valve		Pneumatic diaphragm or spring return piston with electro-pneumatic positioner and solenoid valve	
Diaphragm operated 2-way globe valve (fail closed)		Pneumatic diaphragm	
Diaphragm pressure balanced		Pneumatic cylinder single acting	
Pneumatic cylinder double acting		Pressure reducing regulator with external pressure tap	
Pressure safety valve angle patterned			

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skill **1.3-D.1.a.** refer to:
   - Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 1 General Considerations and Chapter 2 Valve Design.

b. For Supporting Knowledge and Skill **1.3-D.1.b.** and **1.4-E.1.a.** refer to:
   - Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 1 General Considerations and Chapter 2 Valve Design.
   - Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Piping, Valves, Gaskets, and Packing.

c. For Supporting Knowledge and Skill **1.3-D.1.c.** refer to:
   - Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 2 Valve Design.
   - Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Piping, Valves, Gaskets, and Packing.

d. For Supporting Knowledge and Skill **1.3-D.1.d.** refer to:
   - Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 4 General Purpose Valves, Chapter 5 Check Valves, Chapter 6 Special Service Valves, Chapter 7 Valve Packing.
   - Considine, Douglas M., P.E. (1993). Process/Industrial Instruments & Control Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-012445-0. Section 9, Valves, Servos, Motors and Robots.
   - Nayyar, Mohinder, P.E. (1992). Piping Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8. Part C, Water Systems Piping.
   - Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Piping, Valves, Gaskets, and Packing.

e. For Supporting Knowledge and Skill **1.3-D.1.e.** and **1.4-E.1.b.** refer to:
- Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 2 Valve Design, Chapter General Purpose Valves, Chapter 5 Check Valves, Chapter 6 Special Service Valves.
- Considine, Douglas M., P.E. (1993). Process/Industrial Instruments & Control Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-012445-0. Section 9, Valves, Servos, Motors and Robots.
- Nayyar, Mohinder, P.E. (1992). Piping Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8. Part C, Water Systems Piping.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Piping, Valves, Gaskets, and Packing.

f. For Supporting Knowledge and Skill **1.3-D.1.f.** and **1.4-E.1.d.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valves.

g. For Supporting Knowledge and Skill **1.3-D.1.g.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valves.
- Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 3 Flow Through Valves.

h. For Supporting Knowledge and Skill **1.3-D.1.h.** and **1.4-E.1.e.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valves.
- Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 3 Flow Through Valves, Chapter 4 General Purpose Valves.

i. For Supporting Knowledge and Skill **1.3-D.1.i.** and **1.4-E.1.g.** refer to:
- Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 2 Valve Design.
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valves.

j. For Supporting Knowledge and Skill **1.3-D.1.j.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valve Actuators and Positioners.

k. For Supporting Knowledge and Skill **1.3-D.1.k.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valves.
   - Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 6 Special Service Valves.

l. For Supporting Knowledge and Skill **1.3-D.1.l.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valves.
   - Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 6 Special Service Valves.

m. For Supporting Knowledge and Skill **1.3-D.1.m.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Heat Transfer and Fluid Flow Study Guide (NWMOG009.H0103) Chapter Water Hammer and Hydraulic Shock.

n. For Supporting Knowledge and Skill **1.4-E.1.c.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valves.
   - Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 3 Flow Through Valves.

o. For Supporting Knowledge and Skill **1.4-E.1.f.** refer to:

p. For Supporting Knowledge and Skill **1.4-E.1.h.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valves.

q. For Supporting Knowledge and Skill **1.4-E.1.i.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valve Actuators and Positioners.
- Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 6 Special Service Valves.

r. For Supporting Knowledge and Skill **1.4-E.1.j.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valve Actuators and Positioners.
- Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 6 Special Service Valves.

s. For Supporting Knowledge and Skill **1.4-E.1.k.** refer to:
- Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 6 Special Service Valves.

t. For Supporting Knowledge and Skill **1.4-E.1.l.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Valve Actuators and Positioners.
- Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39. Chapter 6 Special Service Valves.

u. For Supporting Knowledge and Skill **1.4-E.1.m.** refer to:
- American National Standards Institute/ American Society of Mechanical Engineers ANSI/ASME OM-1 Requirements for Inservice Performance Testing of Nuclear Power Plant Pressure Relief Devices

4. Practice Exercise

a. Describe the four (4) methods of flow control elements of valve design? (K&S 1.3-D.1.a.) And give an example of the types of valve that would operate that way. (K&S 1.3-D.1.d.)

1)
Example valve type:

2)
Example valve type:

3)
Example valve type:

4)
Example valve type:

b. What are the seven (7) main parts of a typical valve? (K&S 1.3-D.1.b.) (K&S 1.4-E.1.a.)

1•
2•
3•
4•
5•
6•
7•

c. What part of a typical valve provides the main pressure boundary for the fluid in the valve and provides a connection place for the remaining parts of the valve? (K&S 1.3-D.1.b.) (K&S 1.4-E.1.a.)

d. What problem is a result of the packing in a valve being to tight? (K&S 1.3-D.1.b.) (K&S 1.4-E.1.a.)

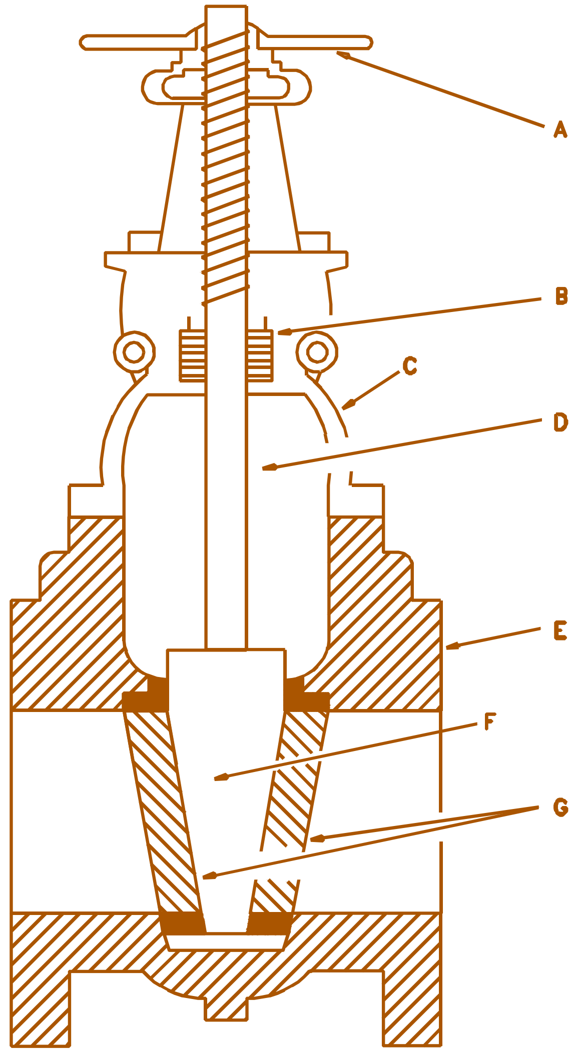
e. Match the valve component purposes below with the components shown in the cutaway figure to the right. Use the components in the cutaway one time only. Ignore any component in the figure not listed below. (K&S 1.3-D.1.c.)

__ 1. The primary pressure boundary of the valve and the principle part of the valve because it holds everything together.

__ 2. Connects the actuator and the disk and is responsible for positioning the disk.

__ 3. A fibrous material or other compound that forms a seal between the internal parts of a valve and the outside where the stem extends through the body.

__ 4. The cover for the opening on the valve body.

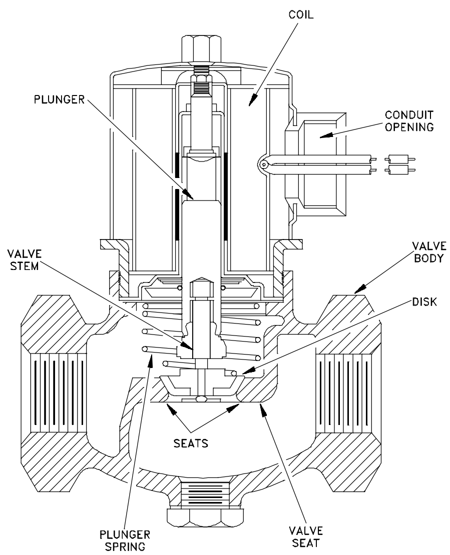


f. Describe the basic operation of a **BUTTERFLY** valve. (K&S 1.3-D.1.d.)

g. Describe the basic operation of a **DIAPHRAGM** valve. (K&S 1.3-D.1.d.)

h. Which type of **VALVE** is described in the following. "Uses rotational motion of a spherical-shaped disk to stop or start fluid flow. Quick acting type requiring only a 90 degree of the valve handle to operate the valve. They also require no lubrication resulting in a tight sealing with low torque." (K&S 1.3-D.1.d.)

i. What type of **VALVE** is shown in the figure below? (K&S 1.3-D.1.e.) (K&S 1.4-E.1.b.)



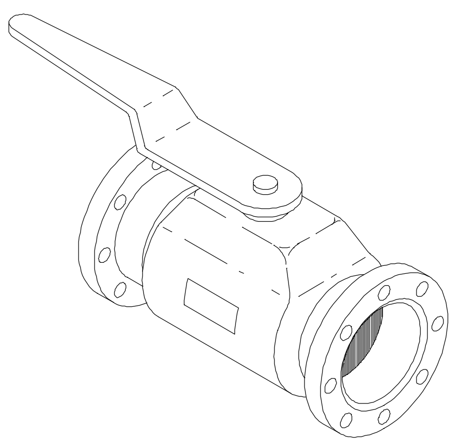
j. List the types of valves that are used to throttle flow. (K&S 1.3-D.1.g.)

k. List two (2) problems associated with using a gate valves to throttle flow. (K&S 1.3-D.1.h.) (K&S 1.4-E.1.e.)

   1.

   2.

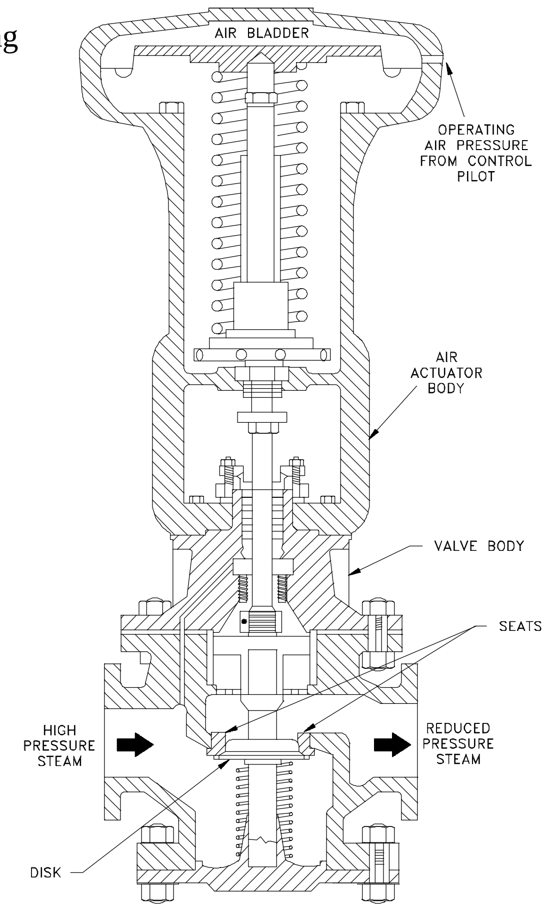
l. Which type of **VALVE** would use the manual actor shown in the figure below? (K&S 1.3-D.1.i.) (K&S 1.4-E.1.g.)



m. Refer to the figure of the manual actor shown above. What is the position of the valve? (K&S 1.3-D.1.i.) (K&S 1.4-E.1.g.)
   a. Closed
   b. Intermediate
   c. Open
   d. Undetermined

n. Describe the construction and principle of operation of an electric motor valve actuator. (K&S 1.3-D.1.i.) (K&S 1.4-E.1.g.)

o. Refer to the valve **ACTUATOR** shown in the figure to the right and answer the following questions. (K&S 1.3-D.1.i.) (K&S 1.4-E.1.g.)



1) What type of actuator is shown?
   a) Electric
   b) Hydraulic
   c) Pneumatic
   d) Solenoid

2) What type of actuator is shown?
   a) Diaphragm
   b) Piston
   c) Reducing
   d) Spring

3) What is the failure mode of the valve and actuator?
   a) Fail Open
   b) Fail Closed
   c) Fail As is
   d) Fail Safe

p. The difference between the setpoint pressure and the pressure which a relief valve is fully open is called? (K&S 1.3-D.1.k.) (K&S 1.4-E.1.i.)

1) Accumulation

2) Blowdown

3) Simmer

4) Weeping

q. A steam system requires protection from over pressurization which type of valve should be used? (K&S 1.3-D.1.l.) (K&S 1.4-E.1.j.)

1) Safety valve

2) Check valve

3) Three-way pilot-actuated valve

4) Relief valve

r. Discuss how valve operation controlled by a process control system can cause water hammer or pressure spiking if the system is not designed properly. (K&S 1.3-D.1.m.)

s. Discuss why the design of a globe valve enables it to throttle fluids efficiently. (K&S 1.4-E.1.c.)

5. Practice Exercise Answers

a. Describe the four (4) methods of flow control elements of valve design? (K&S 1.3-D.1.a.) And give an example of the types of valve that would operate that way. (K&S 1.3-D.1.d.)

1) Move a disk, or plug into or against an orifice.
   Example valve type: Globe; Relief; Safety; Check

2) Slide a flat, cylindrical, or spherical surface across a orifice.
   Example valve type: Gate

3) Rotate a disk or ellipse about a shaft extending across the diameter of an orifice.
   Example valve type: Ball; Butterfly; Plug

4) Move flexible material into a flow passage.
   Example valve type: Diaphragm

b. What are the seven (7) main parts of a typical valve? (K&S 1.3-D.1.b.) (K&S 1.4-E.1.a.)

- Body
- Bonnet
- Stem
- Actuator
- Packing
- Seat
- Disk

c. What part of a typical valve provides the main pressure boundary for the fluid in the valve and provides a connection place for the remaining parts of the valve? (K&S 1.3-D.1.b.) (K&S 1.4-E.1.a.)

Body

d. What problem is a result of the packing in a valve being to tight? (K&S 1.3-D.1.b.) (K&S 1.4-E.1.a.)

The valve stem may not operate with normal actuating force.

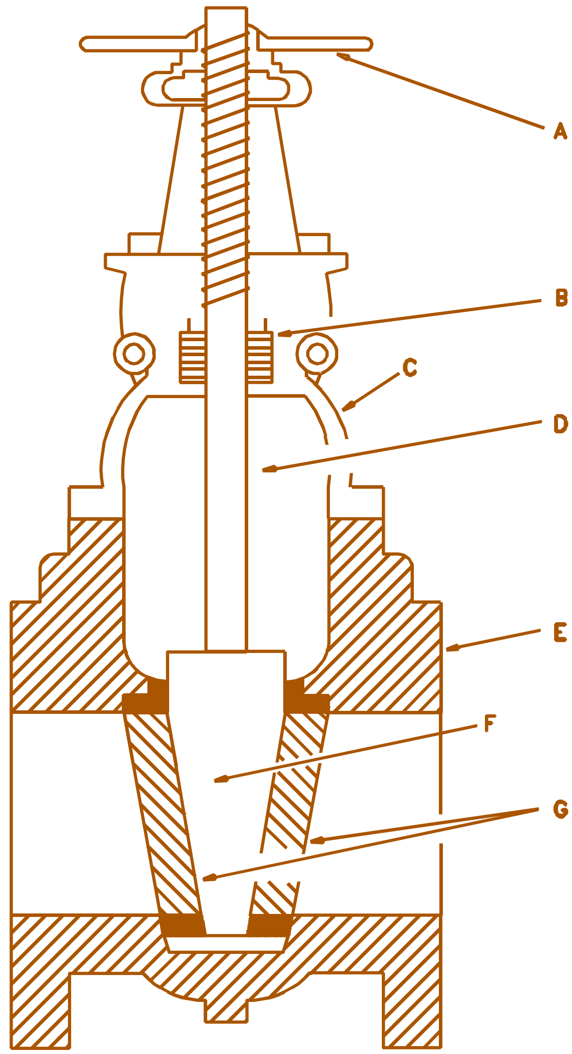
e. Match the valve component purposes below with the components shown in the cutaway figure to the right. Use the components in the cutaway one time only. Ignore any component in the figure not listed below. (K&S 1.3-D.1.c.)

_e_ 1. The primary pressure boundary of the valve and the principle part of the valve because it holds everything together.

_d_ 2. Connects the actuator and the disk and is responsible for positioning the disk.

_b_ 3. A fibrous material or other compound that forms a seal between the internal parts of a valve and the outside where the stem extends through the body.

_c_ 4. The cover for the opening on the valve body.



f. Describe the basic operation of a **BUTTERFLY** valve. (K&S 1.3-D.1.d.)

A rotary motion valve that is used to stop, regulate, and start fluid flow. These valves are quickly operated because a 90 degree rotation of the handle moves the disk from closed to open.

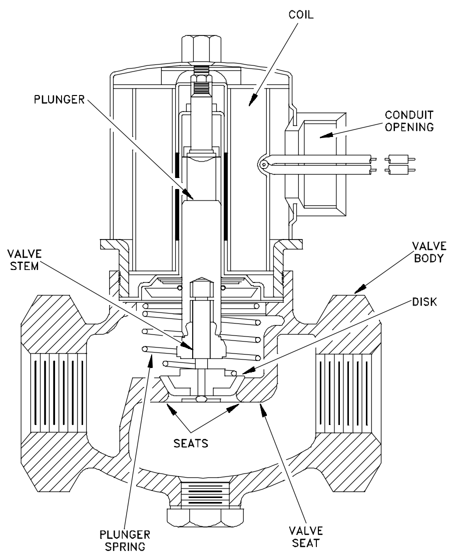
g. Describe the basic operation of a **DIAPHRAGM** valve. (K&S 1.3-D.1.d.)

A linear motion valve used to start, regulate, and stop fluid flow. Diaphragm valves are also called "pinch clamp" valves. A flexible diaphragm is connected to compressor by a stud molded into a diaphragm. The compressor is moved up and down by the valve stem. When the stem is raised, the diaphragm is lifted, when the stem is lowered, the diaphragm is lowered against the contoured bottom of the valve.

h. Which type of **VALVE** is described in the following. "Uses rotational motion of a spherical-shaped disk to stop or start fluid flow. Quick acting type requiring only a 90 degree of the valve handle to operate the valve. They also require no lubrication resulting in a tight sealing with low torque." (K&S 1.3-D.1.d.)

Ball

i. What type of **VALVE** is shown in the figure below? (K&S 1.3-D.1.e.) (K&S 1.4-E.1.b.)



Globe

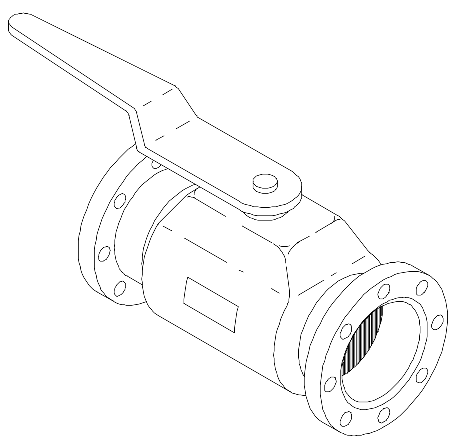
j. List the types of valves that are used to throttle flow. (K&S 1.3-D.1.g.)

Globe valve and diaphragm valve are valid throttle valves. Other valves sometimes used as throttle valves butterfly valves, ball valve, plug valve. These valve are sometimes used as throttle valves, but some sources suggest or recommend that they only be used as isolation valves not as throttle valves.

k. List two (2) problems associated with using a gate valves to throttle flow. (K&S 1.3-D.1.h.) (K&S 1.4-E.1.e.)

1. The flowrate does not always change the same amount for the same amount of movement of the handwheel. The flowpath is enlarged in a nonlinearly manner in respect to the percent open. Turning the handwheel a certain amount will not always create the same
2. The disk is prone to vibration in the partially open position, causing wear and damage to the seat or disk.
3. The high velocity flowrate through the partially open seat and disk is subject to more wear than a globe valve.
4. Repair to damaged gate valves generally more difficult to accomplish.

l. Which type of **VALVE** would use the manual actor shown in the figure below? (K&S 1.3-D.1.i.) (K&S 1.4-E.1.g.)



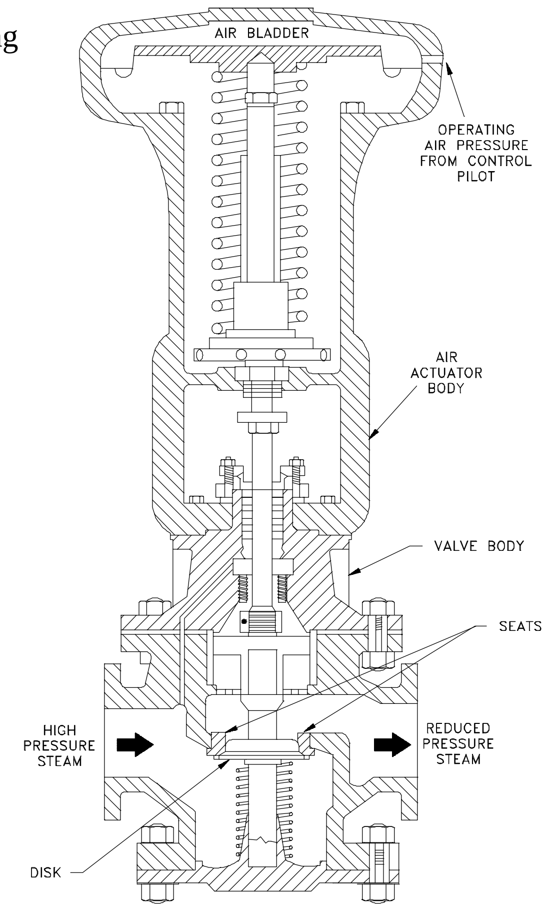
Ball, Butterfly, Plug

m. Refer to the figure of the manual actor shown above. What is the position of the valve? (K&S 1.3-D.1.i.) (K&S 1.4-E.1.g.)
   a. Closed
   b. Intermediate
   c. Open
   d. Undetermined

n. Describe the construction and principle of operation of an electric motor valve actuator. (K&S 1.3-D.1.i.) (K&S 1.4-E.1.g.)

Consist of reversible electric motors connected to the valve stem through a gear train that reduces rotational speed and increases torque. The direction of the motor rotation determines the travel movement of the stem. The electrical actuation can be semi-automatic or automatic.

o. Refer to the valve **ACTUATOR** shown in the figure to the right and answer the following questions. (K&S 1.3-D.1.i.) (K&S 1.4-E.1.g.)



1) What type of actuator is shown?
   a) Electric
   b) Hydraulic
   c) Pneumatic
   d) Solenoid

2) What type of actuator is shown?
   a) Diaphragm
   b) Piston
   c) Reducing
   d) Spring

3) What is the failure mode of the valve and actuator?
   a) Fail Open
   b) Fail Closed
   c) Fail As is
   d) Fail Safe

p. The difference between the setpoint pressure and the pressure which a relief valve is fully open is called? (K&S 1.3-D.1.k.) (K&S 1.4-E.1.i.)

1) Accumulation

2) Blowdown

3) Simmer

4) Weeping

q. A steam system requires protection from over pressurization which type of valve should be used? (K&S 1.3-D.1.l.) (K&S 1.4-E.1.j.)

1) Safety valve

2) Check valve

3) Three-way pilot-actuated valve

4) Relief valve

r. Discuss how valve operation controlled by a process control system can cause water hammer or pressure spiking if the system is not designed properly. (K&S 1.3-D.1.m.)

By proper sizing of the valve and actuator and proper operator action when operating the valve.

s. Discuss why the design of a globe valve enables it to throttle fluids efficiently. (K&S 1.4-E.1.c.)

The primary principle of a globe valve operation is the perpendicular movement of the disk away from the seat. This causes the space between the disk and seat to gradually close as the valve is closed. This characteristic gives the globe valve throttling ability and efficiently regulates the flow. The good throttling characteristic occurs because the linear relationship between valve stem/disk movement and the area for the fluid to flow through. The increase in area downstream of the disk and seat and the tortuous path the fluid travels increases the turbulence. The increase in turbulence decreases the pressure. The decrease in pressure reduces the driving head which moves fluid through the pipe.

This page is intentionally blank.

F. **Competency 1.5**

Construction management and engineering (FAC# 1.24), EH Residents (FAC# 1.4), Facility maintenance management (FAC# 1.6), Facility representatives (FAC# 1.4), and Instrumentation and control (FAC# 1.17) personnel shall demonstrate familiarity level knowledge of pump construction, operations, and theory.

1. Supporting Knowledge and Skills

   a. Define the following terms as they relate to pumps:

      - Head
      - Net positive suction head (NPSH)
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 12-13.
        DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Chapter Centrifugal Pump Operation.
      - Cavitation
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 12, 13.
        DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Chapter Centrifugal Pump Operation.
      - Shut-off head
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 14.
      - Run-out
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 15.

   b. Describe the function, construction, and operation of the following types of pumps:

      - Centrifugal pump
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pumps, page 1-10.
      - Positive displacement pump
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Positive Displacement Pumps, page 18-28.
      - Single stage and multiple stage pumps
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pumps, page 6-7.

- Submersible pumps

c. Describe the general principle of operation and pressure/flow characteristics for positive displacement pumps.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Positive Displacement Pumps, page 18-27.

d. Describe the general principle of operation and pressure/flow characteristics for centrifugal pumps.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pumps, page 1 and Chapter Centrifugal Pump Operation, page 13-14.
   DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Chapter Centrifugal Pump Operation.

e. Given a cutaway drawing of a centrifugal pump, identify the following components and discuss their purpose:

   - Impeller
   - Packing or mechanical seal
   - Volute

   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pumps, page 2-9.

f. Discuss why centrifugal pumps should always be started against a shut-off head.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 14-15.

g. State the dangers to personnel and equipment associated with starting a positive displacement pump against a shut-off head.

h. Discuss the concept of pump cavitation and describe its harmful effects.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 12-13.
   DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Chapter Centrifugal Pump Operation.

i. Describe the function and operation of vibration monitoring equipment used to monitor large motors, pumps, and compressors.

G. **Competency 1.6**

Mechanical systems (FAC# 1.8) personnel shall demonstrate a working level knowledge of pump theory and operation.

1. Supporting Knowledge and Skills

   a. Define the following terms as they relate to pumps:

      - Head
      - Net positive suction head (NPSH)
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 12-13.
        DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Chapter Centrifugal Pump Operation.
      - Cavitation
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 12, 13.
        DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Chapter Centrifugal Pump Operation.
      - Shut-off head
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 14.
      - Run-out
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 15.

   b. Describe the general principle of operation for centrifugal pumps.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pumps, page 1 and Chapter Centrifugal Pump Operation, page 13-14.

   c. Describe the general principle of operation for positive displacement pumps.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Positive Displacement Pumps, page 18-27.

d. Using a cutaway drawing of a centrifugal pump, identify the following components and discuss their purpose:
   - Impeller
   - Packing or mechanical seal
   - Volute
   - Lantern ring
   - Wearing rings (impeller and/or casing)

   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pumps, page 2-9.

e. Discuss Bernoulli's Law as it applies to the design and operation of centrifugal pumps.

f. Discuss why centrifugal pumps should always be started against a shut-off head.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 14-15.

g. Compare and contrast the principle of operation and typical pumped medium of the following types of positive displacement pumps:

   - Reciprocating
     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Positive Displacement Pumps, page 19-21.
   - Rotary-screw
     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Positive Displacement Pumps, page 22-25.
   - Vane-axial
     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Positive Displacement Pumps, page 26 and Volume 2 of 2, Module 5, Chapter Miscellaneous Mechanical Components, page 4-5.

h. Using a cutaway drawing of rotary-screw positive displacement pump, identify and discuss the purpose of the following components:

   - Driver screw
   - Idler screw(s)

   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Positive Displacement Pumps, page 24-25.

i. State the dangers to personnel and equipment associated with starting a positive displacement pump against a shut-off head.

j. Using the following list of system and/or pumped medium characteristics, identify which type of pump (e.g., centrifugal, reciprocating positive displacement, rotary-screw positive displacement) is best suited for the application.

  - Slurries
  - Fluids with high viscosities
  - Low volume, high head
  - Low head, high volume
  - Water
  - Oil

k. Discuss the concept of pump cavitation and describe its harmful effects.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 12-13.
   DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow (DOE-HDBK-1012/3-92) Volume 3 of 3, Chapter Centrifugal Pump Operation.

l. Discuss the methods available (ultrasound, infrared, etc.) for monitoring pump cavitation.

2. Self-Study Information

Competency 1.5 and 1.6 address pump construction, theory, and purpose. Competency 1.5 at a familiarity level and Competency 1.6 at a working level of knowledge.

The supporting material for the Self-Study Activities include the following documents:

- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2
- Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 106
- Westinghouse Savannah River Company High Level Waste Operator Training Program Heat Transfer and Fluid Flow (NWMOG009.H0103)
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102)
- Electric Power Research Institute (1982). <u>EPRI CS-2725, Vibration & Balance Problems</u>.

- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.
- Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4.
- Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications.
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4.
- Walker, Rodger (1972). Pump Selection: A Consulting Engineers's Manual. Ann Arbor, MI: Ann Arbor Science Publishers Inc. ISBN 0-250-40005-7.

Head - the pressure equated to a column height of water in feet. The height of a column of water a pressure would support. Used as a conversion between pressure (pounds force per square inch) and a height of water the pressure would support.

$$\frac{14.7\ \text{lbf}}{\text{in}^2}\left|\frac{144\ \text{in}^2}{\text{ft}^2}\right|\frac{\text{lbm}\cdot\text{s}^2}{32.17\ \text{ft}\cdot\text{lbf}}\left|\frac{\text{ft}^3}{62.4\ \text{lbm}}\right|\frac{32.17\ \text{ft}}{\text{s}^2} = 39.92\ \text{ft of } H_2O$$

Submersible pumps - is a pump design to operate while submerged. The pump can have a sealed electrical motor connected directly to the pump that is also submerged or the pump can be submerged and the motor above or outside the liquid and be connected to the pump via an extended pump shaft or gearing arrangement. A common example of a submersible pump is a sump pump. The benefit of a submersible pump is that the suction has minimal losses as there is no head loss due to suction piping.

Bernoulli's Law and Centrifugal Pumps

The spinning impeller flings the water out of the impeller into the volute area of the pump casing. This creates a low pressure region in the eye of the impeller which draws much water in from the suction. The high speed water exiting the impeller enters the expanding area of the volute. The volute has a gradually expanding area. As the area increases the velocity decreases. The law of conservation of energy says that energy can neither be created nor destroyed. The energy from the velocity of the water at the entrance to the volute is transformed into pressure at the exit of the volute.

One form of Bernoulli's equation is: $\Delta pe + \Delta ke + \nu\Delta p = 0$

The small change in height that occurs in centrifugal pumps, even large centrifugal pumps is very small as to be negligible. If the assumption is made that there is no change in the potential energy in the pump then the term Δpe is equal to zero. If the pump is considered to be pumping an incompressible fluid, then the assumption can be made that the specific volume (ν) is constant. Expanding and rearranging the equation becomes:

$$p_2 = p_1 + \frac{ke_1 - ke_2}{\nu}$$

Assuming the values at point one (the inlet to the volute) remain constant, the decrease in velocity at point two (the exit of the volute) becomes an increase in pressure at the exit of the volute.

$$\uparrow p_2 = \overset{\leftrightarrow}{p_1} + \frac{\overset{\leftrightarrow}{ke_1} - \overset{\downarrow}{ke_2}}{\overset{\leftrightarrow}{\nu}}$$

Starting Centrifugal Pumps

Prior to the initial starting of a centrifugal pump the rotation of the prime mover should be check for the correct direction of rotation. Some pumps have arrows on the pump casing to show the correct direction of rotation. The impeller of the pump should rotate such that the curvature of the impeller blades is flinging the water outward not scooping the fluid. All bearing should be checked for proper lubrication. The pump should be rotated by hand prior to starting to ensure free rotation. Pumps supplied with external cooling water should be checked to ensure adequate supply of cooling water. The water temperature and flow should be regulated to maintain an even warm temperature of the bearings, not too cool but not overheating either.

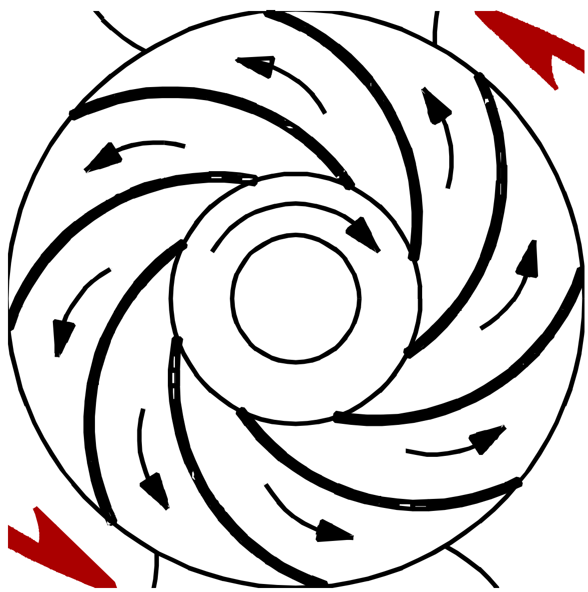


Figure 31 Correct Pump Rotation

Centrifugal pumps should be primed before starting. This requires that the pump casing be filled with liquid and the gases removed. This is accomplished by opening the vent lines until a steady stream of liquid flow from the vent lines. The vent lines must then be closed. If the pump has not been operated in an extended period of time it is also recommended that the pump shaft be rotated several times and the pump re-vented. Priming of centrifugal pumps is important because they are not designed to move gases. If the gases are not removed adequate liquid flow through the pumps will not be established and the pump may be damaged by overheating.

Basic step for starting a centrifugal pump (actual plant procedures are to be followed, these are just general guidelines):

(a) Rotate the rotor by hand to ensure free rotation.
(b) Ensure the suction valves are open.
(c) Ensure the discharge valves are closed.
(d) Ensure power available to the prime mover.
(e) Ensure cooling water available.
(f) Open vent valves to relieve air pockets.
(g) Close vent valves when clear steady stream of liquid flows.
(h) Start the pump.
(i) Observe pump and motor indications.
(j) Open the discharge valves.
(k) Ensure the pump packing flow is adequate.
(l) Ensure adequate cooling water supplied to maintain bearing temperatures.

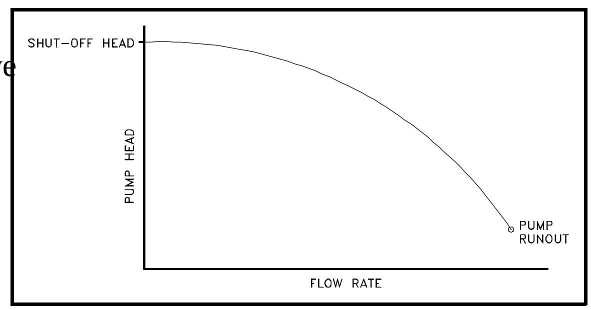


Figure 32 Centrifugal Pump Characteristic Curve

Centrifugal pumps are started against a shutoff head to prevent drawing excessive starting currents when the pump motor is first started. If the pump is started with the discharge valve open, the pump will start with minimum pressure and maximum flow. The pump will be rotating at maximum speed. Based on the pump laws for centrifugal pumps the power is proportional to the pump speed cubed ($Hp \propto n^3$). With the discharge valve closed the pump will operate at 35-50% full load. When the pump starts with the discharge valves closed, the motor will draw 5-7 times the normal full load current (see discussion on motor operations in Electrical Science Topical Area (SR-TA-ELS-001)). If the discharge valves are not closed the power the motor draws would be even greater. The excess current drawn may exceed the current carrying capacity of the electrical insulation and wires causing the motor to over heat and be damaged.

Centrifugal pumps are cooled by the liquid flowing through the pump. If the pump is operated at low speeds or capacities or with the discharge valve closed for extended periods of time the heat generated in the pump by the fluid friction may cause the pump to over heat. The heat generated may cause the pump metals to expand as they are heated reducing the tolerances. The reduced tolerances between component parts (between wearing rings or between the impeller and casing) may cause the parts to rub and wear against one another damaging the parts and the pump. The recirculation line may assist in allowing some flow through the pump with the discharge valve closed. The recirculation line taps off the discharge line upstream of the discharge valves. The line runs from the discharge line back to the pump suction. If the discharge valve is closed a small percentage ($\approx$10%) is recirculated back to the suction.

Positive displacement pump and shut-off head

Basic step for starting a positive displacement pump (actual plant procedures are to be followed, these are just general guidelines):

(1) Ensure the suction **AND** discharge valves are open.
(2) Ensure power available to the prime mover.
(3) Ensure cooling water available.
(4) Open vent valves to relieve air pockets.
(5) Close vent valves when clear steady stream of liquid flows.
(6) Start the pump.
(7) Observe pump and motor indications.
(8) Ensure the pump packing flow is adequate.
(9) Ensure adequate cooling water supplied to maintain bearing temperatures.

Although positive displacement pumps are self priming and can pump gases, priming the pump before starting the pump is often recommended.

Positive displacement pumps operate by displacing or moving a fixed amount of fluid with every stroke or rotation. It is important to ensure that the discharge valve is open before starting a positive displacement pump. If the discharge valve is not open when the pump is started the fluid moved from in the pump to the discharge line has no where to go. The fluid keeps increasing and the pressure keeps increasing. The pump keeps moving the amount of fluid, if the discharge valve is closed the pressure keeps increasing until the relief valve opens as designed or until the pressure exceeds the strength of the pump or piping components. If the relief valve failed to open or a weakness or flaw exists in the pump or piping the over pressurization could result in catastrophic failure of the components or pump.

Cavitation

Cavitation is the formation of vapor bubbles in the low pressure region of a pump and the subsequent collapse of the bubbles in the high pressure regions of the pump.

Possible causes:

(1) Impeller travelling faster than the liquid can keep up with it.
  (a) Speed of impeller to fast for the operating conditions (temperature/pressure)
(2) Suction piping restricted
  (a) Strainer clogged
  (b) Suction valve throttled
  (c) Excessive restrictions/elbows in suction piping
(3) Temperature to high for the suction conditions
(4) Not enough pressure above the surface of the liquid

Operator actions to prevent/reduce cavitation:

(1) Slow down the speed of the impeller
(2) Clean/switch the suction strainer
(3) Open/check open the suction valve
(4) Increase cooling of the supply
(5) Pressurize the supply tank

Pump applications

Some important considerations when selecting a pump:

(1) Capacity or flow rate
(2) Pressure to be developed or necessary to maintain flow
(3) Viscosity of fluid
(4) Particulate content
(5) Chemical content or corrosiveness of fluid

Type of Fluid	Recommend type of Pump
Slurries	Centrifugal pumps with open or semi-open impellers Diaphragm positive displacement pumps Jet pumps, eductors, or ejectors
Fluids with high viscosities	Rotary or screw type positive displacement pumps
Low volume, high head	Positive displacement pumps
Low head, high volume	Centrifugal pumps
Water	Centrifugal pumps or Positive displacement pumps (Dependent on head and flow requirements)
Oil	Rotary or screw type positive displacement pumps (dependent on viscosity and temperature)

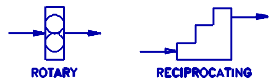
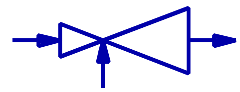
Vibration monitoring

Shutting down large motors, pumps, turbines, generators and compressors for preventive maintenance affects the operation of the entire plant. However it is still better to shutdown a piece of equipment for maintenance rather than because of damage to the equipment. It can be costly, inconvenient, or impractical to take the equipment out of service on a regular basis. Predictive maintenance is the process where certain parameters of a piece of equipment are monitored to identify changes which may predict when the equipment is reaching a point of failure.

Over time, it has been found that by monitoring certain parameters, such as vibration, the time between equipment maintenance can be extended. These parameters are monitored and recorded and by analyzing the changes in a certain equipment performance parameter, a better projection can be made as to when the equipment should be taken out of service.

Plant equipment such as large motors, pumps, turbines, generators and compressors are monitored using vibration monitoring equipment such as spectrum analyzers and computers. This equipment uses sensors such as velocity pickups, accelerometers, proximity probes with oscillator/demodulators, etc.

Figure 33 PUMP SYMBOLS

Positive displacement Pumps		Centrifugal Pump	
		Eductor	

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **1.5-F.1.a.** and **1.6-G.1.a.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Positive Displacement Pumps; Chapter Centrifugal Pumps.
   - Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 2 Principles of Hydraulics.
   - Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Pumps and Chapter Pump Operation and Maintenance.

b. For Supporting Knowledge and Skills **1.5-F.1.b.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Positive Displacement Pumps; Chapter Centrifugal Pumps.
   - Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications. Chapter Pumps page 138 -140.
   - Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 3 Centrifugal Pumps; Chapter 4 Rotary Pumps; Chapter 5 Reciprocating Pumps; Chapter 6 Special Service Pumps.

- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Pumps and Chapter Pump Operation and Maintenance.

c. For Supporting Knowledge and Skills **1.5-F.1.c.** and **1.6-G.1.c.** refer to:
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Positive Displacement Pumps; Chapter Centrifugal Pumps.
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 4 Rotary Pumps; Chapter 5 Reciprocating Pumps; Chapter 6 Special Service Pumps.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Pumps and Chapter Pump Operation and Maintenance.

d. For Supporting Knowledge and Skills **1.5-F.1.d.** and **1.6-G.1.b.** refer to:
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Centrifugal Pumps.
- Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications. Chapter Pumps page 148.
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 3 Centrifugal Pumps.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Pumps and Chapter Pump Operation and Maintenance.

e. For Supporting Knowledge and Skills **1.5-F.1.e.** and **1.6-G.1.d.** refer to:
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Centrifugal Pumps.
- Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications. Chapter Pumps page 144 - 146.
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 3 Centrifugal Pumps.

- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Pumps and Chapter Pump Operation and Maintenance.

f. For Supporting Knowledge and Skills **1.5-F.1.f.** and **1.6-G.1.f.** refer to:
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 3 Centrifugal Pumps.
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Positive Displacement Pumps; Chapter Centrifugal Pumps.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Pumps and Chapter Pump Operation and Maintenance.

g. For Supporting Knowledge and Skills **1.5-F.1.g.** and **1.6-G.1.i.** refer to:
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Positive Displacement Pumps
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 4 Rotary Pumps; Chapter 5 Reciprocating Pumps; Chapter 6 Special Service Pumps.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Pumps and Chapter Pump Operation and Maintenance.

h. For Supporting Knowledge and Skills **1.5-F.1.h.** and **1.6-G.1.k.** refer to:
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Centrifugal Pumps.
- Walker, Rodger (1972). Pump Selection: A Consulting Engineers's Manual. Ann Arbor, MI: Ann Arbor Science Publishers Inc. ISBN 0-250-40005-7.
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 3 Centrifugal Pumps.

i. For Supporting Knowledge and Skills **1.5-F.1.i.** and **1.6-G.1.l.** refer to:
- Electric Power Research Institute (1982). EPRI CS-2725, Vibration & Balance Problems.

j. For Supporting Knowledge and Skills **1.6-G.1.e.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Positive Displacement Pumps; Chapter Centrifugal Pumps.
   - Westinghouse Savannah River Company High Level Waste Operator Training Program Heat Transfer and Fluid Flow (NWMOG009.H0103) Chapter Fluid Dynamics.

k. For Supporting Knowledge and Skills **1.6-G.1.g.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Positive Displacement Pumps.
   - Power. <u>The Engineer's Reference Library</u>. New York, NY: McGraw-Hill Publications. Chapter Pumps page 150-154.
   - Pease, Dudley A. and John J. Pippenger (1987). <u>Basic Fluid Power</u>. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 6 Source of Hydraulic Power.
   - Stewart, Harry L. and Rex Miller (1991 revised). <u>Pumps</u>. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 4 Rotary Pumps; Chapter 5 Reciprocating Pumps; Chapter 6 Special Service Pumps.
   - Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Pumps and Chapter Pump Operation and Maintenance.

l. For Supporting Knowledge and Skills **1.6-G.1.h.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Positive Displacement Pumps.
   - Pease, Dudley A. and John J. Pippenger (1987). <u>Basic Fluid Power</u>. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 6 Source of Hydraulic Power.
   - Stewart, Harry L. and Rex Miller (1991 revised). <u>Pumps</u>. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 4 Rotary Pumps; Chapter 5 Reciprocating Pumps; Chapter 6 Special Service Pumps.
   - Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Pumps and Chapter Pump Operation and Maintenance.

m. For Supporting Knowledge and Skills **1.6-G.1.j.** refer to:

- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Positive Displacement Pumps; Chapter Centrifugal Pumps.
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 3 Centrifugal Pumps; Chapter 4 Rotary Pumps; Chapter 5 Reciprocating Pumps; Chapter 6 Special Service Pumps.

4. Practice Exercise

a. Define the following terms: (K&S 1.5-F.1.a.) (K&S 1.6-G.1.a.)

Cavitation

Gas binding

Net positive suction head

Run-out

Shut-off head

b. Which type of pump is designed to move a constant volume of fluid regardless of opposing pressure. (K&S 1.5-F.1.b.)

c. Describe the principles of operation for a **SINGLE ACTING RECIPROCATING POSITIVE DISPLACEMENT PUMP**. (K&S 1.5-F.1.c.) (K&S 1.6-G.1.c.)

d. Describe the general pressure/flow characteristics for centrifugal pumps. (K&S 1.5-F.1.d.) (K&S 1.6-G.1.b.)

e. In a system using a **CENTRIFUGAL PUMP** what is the effect on the flow rate if the pressure in the system increases? (K&S 1.5-F.1.d.) (K&S 1.6-G.1.b.)

f. In a system using a **CENTRIFUGAL PUMP** what is the effect on the flow rate if the speed of the pump is doubled? (K&S 1.5-F.1.d.) (K&S 1.6-G.1.b.)

g. State the purpose of an **IMPELLER** in a centrifugal pump. (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

h. Discuss the purpose of a **VOLUTE** in a centrifugal pump. (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

i. Which component in a centrifugal pump is describe as "a set of stationary vanes that surround the impeller. The purpose is to increase the efficiency of the pump to allow a less turbulent area for the liquid to reduce in velocity." (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

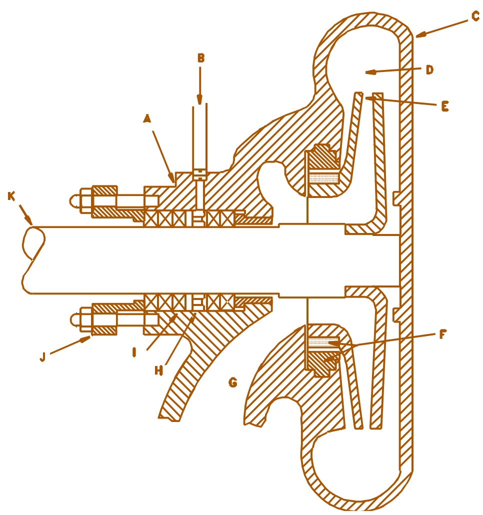
j. Refer to the diagram to the right. State the name of the components identified with the following letters. (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

D) ________________

E) ________________

I) ________________

K) ________________



k. Refer to the diagram above. State the name **AND** purpose of the component identified with the letter "C". (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

l. What position should the following valves be when starting the associate pump? (K&S 1.5-F.1.f.) (K&S 1.6-G.1.f.)(K&S 1.5-F.1.h.)

1) ________ centrifugal pump suction valve

2) ________ positive displacement pump suction valve

3) ________ positive displacement pump discharge valve

4) ________ centrifugal pump discharge valve

m. State the dangers to personnel and equipment associated with starting a positive displacement pump against a shut-off head. (K&S 1.5-F.1.g.) (K&S 1.6-G.1.i.)

n. What damage occurs in a centrifugal pump experiencing **CAVITATION**. (K&S 1.5-F.1.i.) (K&S 1.6-G.1.k.)

o. Can cavitation occur in a **POSITIVE DISPLACEMENT PUMP**? (K&S 1.5-F.1.i.) (K&S 1.6-G.1.k.)

p. List four actions that can be done <u>by the operator</u> to prevent pump cavitation. (K&S 1.5-F.1.i.) (K&S 1.6-G.1.k.)

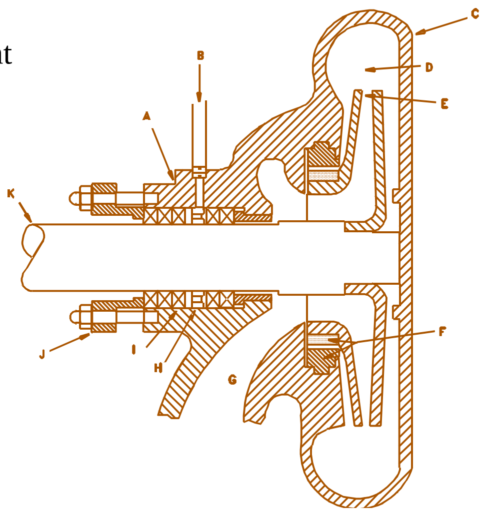
1.

2.

3.

4.

q. Refer to the diagram to the right.
State the name **AND** purpose of the component identified with the letter "H". (K&S 1.6-G.1.d.)



r. Use Bernoulli's Equation to show the energy conversions that occur in a centrifugal pump. (K&S 1.6-G.1.e.)

s. Which type of pump is best suited for pumping slurries? (K&S 1.6-G.1.j.)

t. Which of the following pumps is best suited for fluids with high viscosities? (K&S 1.6-G.1.j.)

1) Centrifugal pump

2) Gear pump

3) Reciprocating pump

4) Eductor

u. In a system using a **POSITIVE DISPLACEMENT PUMP** what is the effect on the flow rate if the pressure in the system increases?

v. In a system using a **POSITIVE DISPLACEMENT PUMP** what is the effect on the flow rate if the speed of the pump is doubled?

5. Practice Exercise Answers

a. Define the following terms: (K&S 1.5-F.1.a.) (K&S 1.6-G.1.a.)

Cavitation	the formation of vapor bubbles in a low pressure region of a pump and their subsequent collapse on a high pressure region.
Gas binding	in a centrifugal pump when the pump casing is filled with non-condensable gases or vapors to the point where the impeller is no longer able to contact enough liquid to function correctly.
Net positive suction head	the difference between the pump suction pressure and the saturation pressure of the liquid being pumped.
Run-out	the condition that exists when the pump differential pressure or head drops below the design minimum discharge differential pressure or head.
Shut-off head	the maximum differential pressure or head that can be developed by a pump operating at a constant set speed and it is the pressure that a pump can no longer move fluid.

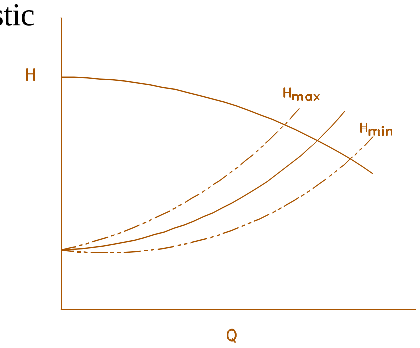
b. Which type of pump is designed to move a constant volume of fluid regardless of opposing pressure. (K&S 1.5-F.1.b.)

A positive displacement pump

c. Describe the principles of operation for a **SINGLE ACTING RECIPROCATING POSITIVE DISPLACEMENT PUMP**. (K&S 1.5-F.1.c.) (K&S 1.6-G.1.c.)

The pump consist of a single piston in a cylinder with a single suction port and a single discharge port. During the suction stroke, the piston moves to the left, causing the suction check valve to open and release water from the reservoir. During the discharge stroke, the piston moves to the right, closing the check valve in the suction line and opening the check valve in the discharge line. This allows the volume of fluid to be discharged.

d. Describe the general pressure/flow characteristics for centrifugal pumps. (K&S 1.5-F.1.d.) (K&S 1.6-G.1.b.)



The pressure flow relationship for a centrifugal pump can be seen using the characteristic curve for the pump. The x axis represents the flow and the y axis represents the head or pressure. When there is no flow the pump generates maximum pressure. This point is called the shut-off head. The point is represented on the graph where the characteristic curve intersects the y axis. At this point all the energy of the is being converted to pressure. As the backpressure on the pump decreases or the discharge valve is opened slowly the flow rate increases and the pressure decreases. As the flow increases the pressure decreases and the curve drops off to the right. The end point of the characteristic curve is the point where there is maximum flow and minimum pressure. On simplistic curves the curve intersects the x axis. On other more exact curve the line simply stops. This point is known as pump run-out.

e. In a system using a **CENTRIFUGAL PUMP** what is the effect on the flow rate if the pressure in the system increases? (K&S 1.5-F.1.d.) (K&S 1.6-G.1.b.)

Flow rate would DECREASE.

f. In a system using a **CENTRIFUGAL PUMP** what is the effect on the flow rate if the speed of the pump is doubled? (K&S 1.5-F.1.d.) (K&S 1.6-G.1.b.)

Flow rate would DOUBLE.

g. State the purpose of an **IMPELLER** in a centrifugal pump. (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

Provides a rotary motion to the liquid forcing it to the outer section of the pump casing where it is collected in the part of the pump casing called the volute.

h. Discuss the purpose of a **VOLUTE** in a centrifugal pump. (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

Collects the liquid discharged from the impeller. The gradual increase in flow area causes a reduction in fluid velocity. This causes an increase in pressure allowing the pump to provide a driving head to move the fluid through the system. The fluid is then discharged from the pump through the discharge connection.

i. Which component in a centrifugal pump is describe as "a set of stationary vanes that surround the impeller. The purpose is to increase the efficiency of the pump to allow a less turbulent area for the liquid to reduce in velocity." (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

Diffuser

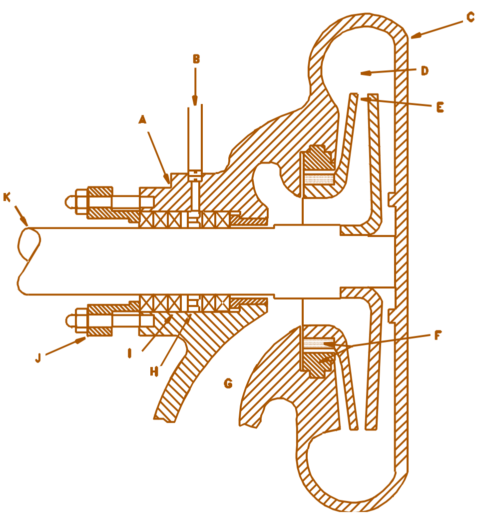
j. Refer to the diagram to the right. State the name of the components identified with the following letters. (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

D) **Volute**

E) **Impeller**

I) **Packing ring (or material)**

K) **Pump Shaft**



k. Refer to the diagram above. State the name **AND** purpose of the component identified with the letter "C". (K&S 1.5-F.1.e.) (K&S 1.6-G.1.d.)

Pump Casing - provides the pressure boundary for the pump internals and directs suction to the center, or eye of the impeller and discharge flow to the discharge piping.

l. What position should the following valves be when starting the associate pump? (K&S 1.5-F.1.f.) (K&S 1.6-G.1.f.)(K&S 1.5-F.1.h.)

1) OPEN centrifugal pump suction valve

2) OPEN positive displacement pump suction valve

3) OPEN positive displacement pump discharge valve

4) CLOSED centrifugal pump discharge valve

m. State the dangers to personnel and equipment associated with starting a positive displacement pump against a shut-off head. (K&S 1.5-F.1.g.) (K&S 1.6-G.1.i.)

Relief valve lift
Piping rupture
Pump rupture

n. What damage occurs in a centrifugal pump experiencing **CAVITATION**. (K&S 1.5-F.1.i.) (K&S 1.6-G.1.k.)

Wear and erosion to the impeller and pump casing in the volute. In extreme cases the shock wave from the collapse of the vapor bubbles may cause the shaft and shaft bearings to wear.

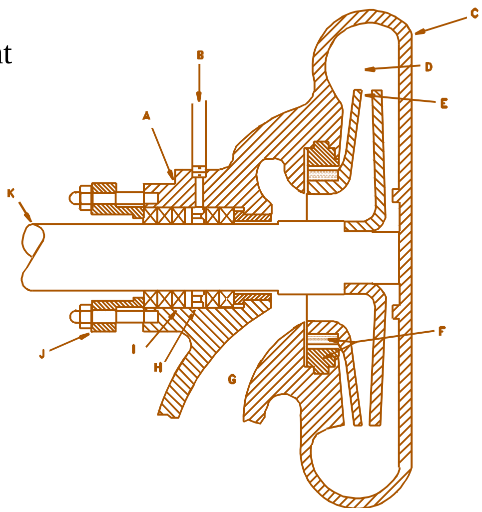
o. Can cavitation occur in a **POSITIVE DISPLACEMENT PUMP**? (K&S 1.5-F.1.i.) (K&S 1.6-G.1.k.)

YES.

p. List four actions that can be done <u>by the operator</u> to prevent pump cavitation. (K&S 1.5-F.1.i.) (K&S 1.6-G.1.k.)

- Decrease the temperature of the fluid being pumped.
- Ensure that the pump suction valve is fully open.
- Reduce the speed of the pump.
- Throttle the discharge valve closed.

q. Refer to the diagram to the right. State the name **AND** purpose of the component identified with the letter "H". (K&S 1.6-G.1.d.)



Lantern ring - receives cool, clean liquid from either the discharge of the pump or an external source and spreads liquid around the shaft to provide cooling, lubrication, and sealing. Prevents air from being drawn into low pressure suction or liquid from pump leaking out along the length of the pump shaft.

r. Use Bernoulli's Equation to show the energy conversions that occur in a centrifugal pump. (K&S 1.6-G.1.e.)

$$\overset{\leftrightarrow}{\rho_1}\ \overset{\leftrightarrow}{A_1}\ \overset{\leftrightarrow}{\vec{v}_1} = \overset{\leftrightarrow}{\rho_2}\ \overset{\uparrow}{A_2}\ \overset{\downarrow}{\vec{v}_2}$$

$$\uparrow p_2 = \overset{\leftrightarrow}{p_1} + \frac{\overset{\leftrightarrow}{ke_1} - \overset{\downarrow}{ke_2}}{\overset{\leftrightarrow}{\nu}}$$

or

$$\uparrow p_2 = \overset{\leftrightarrow}{p_1} + \frac{\overset{\leftrightarrow}{\vec{v}_1^{\,2}} - \overset{\downarrow}{\vec{v}_2^{\,2}}}{\overset{\leftrightarrow}{\nu}}$$

s. Which type of pump is best suited for pumping slurries? (K&S 1.6-G.1.j.)

Centrifugal pumps (Open or semi-open impeller are best)
Diaphragm pumps

t. Which of the following pumps is best suited for fluids with high viscosities? (K&S 1.6-G.1.j.)

   1) Centrifugal pump

   2) Gear pump

   3) Reciprocating pump

   4) Eductor

u. In a system using a **POSITIVE DISPLACEMENT PUMP** what is the effect on the flow rate if the pressure in the system increases?

   Flow rate would REMAIN CONSTANT.

v. In a system using a **POSITIVE DISPLACEMENT PUMP** what is the effect on the flow rate if the speed of the pump is doubled?

   Flow rate would DOUBLE.

H. **Competency 1.7**

Construction management and engineering (FAC# 1.24), EH Residents (FAC# 1.2), Facility maintenance management (FAC# 1.1), Facility representatives (FAC# 1.2 & 1.6), and Instrumentation and control (FAC# 1.17) personnel shall demonstrate familiarity level knowledge of basic pneumatic systems and basic air compressors in the areas of components, operations, and theory.

1. Supporting Knowledge and Skills

   a. Describe the basic operation of a pneumatic system.

   b. Describe the basic design, function, and operation of a compressed air system used to supply instrument air, including piping and instrumentation diagram (P&ID) symbols for the following components:

   - Compressor
   - Moisture separator
   - Intercooler
   - Aftercooler
   - Receiver
   - Air dryer
   - Unloader

     DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Air Compressors, page 1-8.

   c. Define the following terms and discuss their relationship:

   - Dew point
   - Dehydrator
   - Dew point indicator
   - Actuator

   d. Discuss how energy in a pneumatic system is converted to work.

   e. Identify and discuss the general hazards associated with pneumatic systems and their components.

   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Air Compressors, page 7-8.

I. **Competency 1.8**

Mechanical systems (FAC# 1.2) personnel shall demonstrate a working level knowledge of the basic components, operations, and theory of pneumatic systems.

1. Supporting Knowledge and Skills

   a. Define the following terms and discuss their relationship:

      - Dew point
      - Dehydrator
      - Dew point indicator
      - Actuator

   b. Describe the basic operation of a pneumatic system.

   c. Discuss how energy in a pneumatic system is converted to work.

   d. Discuss the hazardous relationship between high pressure air and oil.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Air Compressors, page 8.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Hydraulics, page 12-13.

   e. Identify and discuss the general hazards associated with pneumatic systems and their components.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Air Compressors, page 7-8.

   f. Given a Piping and Instrumentation Diagram (P&ID) of a typical facility instrument air system, identify the main components, their functions, construction, and discuss their relationships, to include:

      - Compressor
      - Dehydrator
      - Receivers
      - Unloader
      - Relief valve

g. Using a cutaway diagram of a typical multi-stage air compressor, identify its main components and discuss their purpose and function to include:

- Prime mover
- High pressure (HP) stage(s)
- Low pressure (LP) stage(s)
- HP and LP suction and discharge valves
- Intercooler
- Aftercooler
- Cooling medium flow path(s)

h. State the purpose of an air compressor unloader and discuss its basic operation.

i. Using a cutaway diagram of a twin-tower pneumatic dehydrator, identify the flow paths and discuss its operation.

2. Self-Study Information

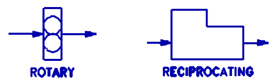
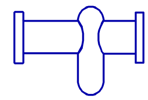
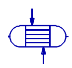
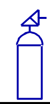
Competency 1.7 and 1.8 address the construction and operation of pneumatics and air compressors. Competency 1.7 at a familiarity level and Competency 1.8 at a working level of knowledge.

The supporting material for the Self-Study Activities include the following documents:

- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2
- Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 7
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101)
- Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.
- Loomis A. W., (1982). <u>Compressed Air and Gas Data</u>. Washington, NJ: Ingersoll-Rand Company.
- Pease, Dudley A. and John J. Pippenger (1987). <u>Basic Fluid Power</u>. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4.
- Technology & Training Group. <u>Industrial Pneumatics</u>. Columbia, MD: General Physics Corp.

- Underwriters Laboratory (UL) Standard 585, High-Efficiency Particulate Air Filter Units

Figure 34 COMPRESSED AIR SYMBOLS

Compressors		Aftercooler with moisture separator	
Cooler or condenser		Gas cylinder	

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **K&S 1.7-H.1.a. and K&S 1.8-I.1.b.** refer to:
   - Loomis A. W., (1982). Compressed Air and Gas Data. Washington, NJ: Ingersoll-Rand Company.
   - Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 14 Controlling Pneumatic Power.
   - Technology & Training Group. Industrial Pneumatics. Columbia, MD: General Physics Corp.

b. For Supporting Knowledge and Skills **K&S 1.7-H.1.b** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Compressed Air.
   - Technology & Training Group. Industrial Pneumatics. Columbia, MD: General Physics Corp.

c. For Supporting Knowledge and Skills **K&S 1.7-H.1.c. and K&S 1.8-I.1.a.** refer to:
   - Loomis A. W., (1982). Compressed Air and Gas Data. Washington, NJ: Ingersoll-Rand Company.
   - Technology & Training Group. Industrial Pneumatics. Columbia, MD: General Physics Corp.

d. For Supporting Knowledge and Skills **K&S 1.7-H.1.d. and K&S 1.8-I.1.c.** refer to:
   - Technology & Training Group. Industrial Pneumatics. Columbia, MD: General Physics Corp.

e. For Supporting Knowledge and Skills **K&S 1.7-H.1.e., K&S 1.8-I.1.d., and K&S 1.8-I.1.e.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Compressed Air.
   - Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Compressed Air Plants.
   - Loomis A. W., (1982). Compressed Air and Gas Data. Washington, NJ: Ingersoll-Rand Company.

f. For Supporting Knowledge and Skills **K&S 1.8-I.1.g.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Compressed Air.
   - Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Compressed Air Plants.
   - Loomis A. W., (1982). <u>Compressed Air and Gas Data</u>. Washington, NJ: Ingersoll-Rand Company.
   - Technology & Training Group. <u>Industrial Pneumatics</u>. Columbia, MD: General Physics Corp.

g. For Supporting Knowledge and Skills **K&S 1.8-I.1.h.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Compressed Air.
   - Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Compressed Air Plants.

h. For Supporting Knowledge and Skills **K&S 1.8-I.1.i.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Compressed Air.

4. Practice Exercise

a. Define the term dewpoint. (K&S 1.7-H.1.c.) (K&S 1.8-I.1.a.)

b. List the four (4) major hazards associated with pneumatic systems and their components. (K&S 1.7-H.1.e.) (K&S 1.8-I.1.d.) (K&S 1.8-I.1.e.)

1.

2.

3.

4.

c. State the purpose of an aftercooler. (K&S 1.8-I.1.g.)

d. State the purpose of an intercooler. (K&S 1.8-I.1.g.)

e. State the purpose of an air compressor unloader and discuss its basic operation. (K&S 1.8-I.1.h.)

f. Using a cutaway diagram of a twin-tower pneumatic dehydrator, identify the flow paths and discuss its operation. (K&S 1.8-I.1.i.)

5. Practice Exercise Answers

a. Define the term dewpoint. (K&S 1.7-H.1.c.) (K&S 1.8-I.1.a.)

The temperature at which the vapor in a space (with a constant pressure) will start to condense and form a vapor.

b. List the four (4) major hazards associated with pneumatic systems and their components. (K&S 1.7-H.1.e.) (K&S 1.8-I.1.d.) (K&S 1.8-I.1.e.)

1. Flying debris caused by compressed air
2. High noise levels
3. Hydraulic shock (water hammer)
4. Combustion of contaminants like oil

c. State the purpose of an aftercooler. (K&S 1.8-I.1.g.)

These coolers remove the heat generated during the compression of the air after the air leaves the compressor. The decrease in temperature promotes the condensing of any moisture present in the compressed air prior to it entering the air system. The moisture is collected in condensate traps that are either automatically or manually drained. The result is drier, cooler compressed air.

d. State the purpose of an intercooler. (K&S 1.8-I.1.g.)

Two stage air compressors often have a water cooled heat exchanger called an intercooler between the first and second stages. The intercooler reduces the second stage air inlet temperature. The lower temperature increases the density of the air an allows the compressor to be more efficient. Since cooling the air also raises its relative humidity, the intercooler will usually have a trap to remove condensation from the compressed air.

e. State the purpose of an air compressor unloader and discuss its basic operation. (K&S 1.8-I.1.h.)

   An unloader is used on a Constant Speed, Pressure Governing Control of the compressor allows the compressor to run continuously. It reduces the wear and tear placed on a compressor that must start up and shut down to control air pressure. A pressure signal from the receiver is sensed by the pressure switch. The contacts of the pressure switch energize and de-energize a solenoid valve. The solenoid valve controls the compressed air control signal to the compressor unloaders. The compressed air control signal actuates these unloaders. When the compressor is running unloaded, the suction valves (or on some models the discharge valves) are held open by the unloaders. This prevents any increase in pressure inside of the cylinder, causing the air in the cylinder to be cycled into and out of the cylinder through the suction valves, rather than to the system.

f. Using a cutaway diagram of a twin-tower pneumatic dehydrator, identify the flow paths and discuss its operation. (K&S 1.8-I.1.i.)

   Desiccant air dryers are filled with a granular, solid desiccant, such as activated alumina or silica gel, which removes water vapor as the air passes through the desiccant bed. Desiccants are hygroscopic materials. That is, they are chemicals that readily take up and retain moisture on their surfaces. One type of desiccant will adsorb approximately 45% of its weight in water. Dryers, normally have two desiccant-filled towers connected in parallel. The desiccant in one of the towers is used to dry the air stream, while the desiccant in the other tower is being regenerated by the application of heat and reverse flow air purge. The water vapor driven off is vented to the atmosphere.

J. **Competency 1.9**

Construction management and engineering (FAC# 1.19), EH Residents (FAC# 1.2), Facility maintenance management (FAC# 1.1), Facility representatives (FAC# 1.2), and Project Management (FAC# 1.1) personnel shall demonstrate familiarity level knowledge of basic hydraulic systems in the areas of components, operations, and theory.

1. Supporting Knowledge and Skills

   a. Define the following and discuss their relationship:

      - Force
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Hydraulics, page 10.
      - Pressure
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Hydraulics, page 10.
      - Pneumatic
      - Hydraulic
      - Dynamic viscosity
      - Kinematic viscosity
      - Specific volume
      - Specific gravity
      - Capillarity
      - Cavitation
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 3, Chapter Centrifugal Pump Operation, page 12, 13.
      - Laminar flow
        DOE Fundamentals Handbook Thermodynamics (DOE-HDBK-1012/3-92) Heat Transfer, and Fluid Flow, Volume 3 of 3, Module 3, Fluid Flow, Chapter Two Phase Fluid Flow and Chapter Laminar and Turbulent Flow.
      - Turbulent flow
        DOE Fundamentals Handbook Thermodynamics (DOE-HDBK-1012/3-92) Heat Transfer, and Fluid Flow, Volume 3 of 3, Module 3, Fluid Flow, Chapter Two Phase Fluid Flow and Chapter Laminar and Turbulent Flow.

b. Discuss the relationship between the following terms:

- Force
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Hydraulics, page 10-11.
- Pressure
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Hydraulics, page 10-11.
- Receiver
- Accumulator
- Actuator

c. Describe the basic operation of a hydraulic system.

d. Given a piping and instrumentation diagram (P&ID) of a typical hydraulic system, identify the main components, their functions, construction, and discuss their relationships, to include:

- Receiver
- Accumulator
- Actuator

DOE Fundamentals Handbook Engineering Fluid Diagrams and Prints (DOE-HDBK-1016/1-93) Volume 1 of 2, Chapter Fluid Power P&IDs.

e. Discuss how energy in a hydraulic system is converted to work.

f. Identify and discuss the hazards associated with hydraulic systems and their components.
DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Hydraulics, page 12-13.

g. Discuss pressurized and non-pressurized flow.

h. Conduct a piping network analysis.

K. **Competency 1.10**

Mechanical systems (FAC# 1.1) personnel shall demonstrate a working level knowledge of the basic components, operations, and theory of hydraulic systems.

1. Supporting Knowledge and Skills

   a. Define the following terms, discuss their relationship in hydraulic systems, and describe the construction of physical components:

      - Force
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Hydraulics, page 10.
      - Work
      - Pressure
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Hydraulics, page 10.
      - Receiver
      - Accumulator
      - Actuator

   b. Describe the basic operation of a hydraulic system.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Hydraulics, page 11-12.

   c. Discuss how energy in a hydraulic system is converted to work.

   d. Identify and discuss the hazards associated with hydraulic systems and their components.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Hydraulics, page 12-13.

   e. Identify the characteristics and special hazards associated with phosphor-based hydraulic oil.

f. Given a piping and instrumentation diagram (P&ID) of a typical hydraulic system, identify the main components, their functions, construction, and discuss their relationships, to include:

- Receiver
- Accumulator
- Actuator

  DOE Fundamentals Handbook Engineering Fluid Diagrams and Prints (DOE-HDBK-1016/1-93) Volume 1 of 2, Chapter Fluid Power P&IDs.

g. Using a cutaway diagram of a multi-port block valve, identify the flow paths and discuss its operation.

DOE Fundamentals Handbook Engineering Fluid Diagrams and Prints (DOE-HDBK-1016/1-93) Volume 1 of 2, Chapter Fluid Power P&IDs.

2. Self-Study Information

Competency 1.9 and 1.10 address the components, operation, and theory associated with hydraulic systems. Competency 1.9 at a familiarity level and Competency 1.10 at a working level of knowledge.

The supporting material for the Self-Study Information include the following documents:

- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2
- DOE Fundamentals Handbook Engineering Fluid Diagrams and Prints (DOE-HDBK-1016/1-93) Volume 1 of 2
- Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 106
- Anders, James E. Sr. (1983). Industrial Hydraulics Troubleshooting. New York, NY: McGraw-Hill Book Company. ISBN 0-07-001592-9.
- Gunther, Raymond C. (1971). Lubrication. Philadelphia, PA: Chilton Book Company. ISBN 0-8019-5526-2.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.
- Nayyar, Mohinder, P.E. (1992). Piping Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8.
- Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4.
- Parker Fluidpower, (1991). Industrial Hydraulic Technology Bulletin 0232-B1. USA: Parker Hannifin Corporation. ISBN 1-55769-000-6.

- Stewart, Harry L. and Rex Miller (revised 1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-6514725-4.

Force - force = pressure times area
Pressure - pressure = force divided by area
Hydraulic - The branch of physics that deals with the mechanical properties of water and other liquids and the application of these properties in engineering systems.
Dynamic viscosity - or absolute viscosity is the physical property of a fluid. It is the ratio of the shear force and the rate or velocity at which the fluid is being sheared. Very viscous (high dynamic viscosity) does not flow readily.
Kinematic viscosity - the ratio of the absolute viscosity of a liquid to it's density.
Specific volume - The volume of a unit mass of a fluid. Typical units are ft^3/lbm (cubic feet per pound mass).
Specific gravity (sg or sp gr) - can be described several ways. It is the ratio of the weight of a fluid of a given volume of a substance to that of an equal volume of standard substance which is used as a comparison. (water for liquids and solids; air or hydrogen for gases.) Specific gravity is the comparison of weight of a liquid to the weight of an equal volume of water. Specific gravity can also be described as the ratio of the specific weight of a given liquid divided by the specific weight of water. Specific gravity is a unitless value as the units in the numerator always cancel out with the units in the denominator. Specific gravity can be used to determine if the fluid in question will float or sink when placed in the comparison fluid (water, air, or hydrogen). If the specific gravity is greater than 1 then the material in question will sink. If the specific gravity is less than 1 then the material in question will float.

$$SG = \frac{\text{weight of liquid}}{\text{weight of equal volume of water}} \quad \text{OR} \quad \frac{\rho_{liquid}}{\rho_{water}}$$

Capillarity - the action by will the surface of a liquid in contact with a solid is elevated or depressed. The action is because of the difference between the attraction of the molecules of the liquid for each other and the attraction to the molecules of the solid. The action is observable in capillary tubes, where the liquid is raised above or depressed below the level of the liquid into which the tube is dipped.
Cavitation - the formation of vapor bubbles in low pressure regions and the subsequent collapse in high pressure regions. The damage occurs from shock waves established by the collapsing bubbles.
Laminar flow - streamlined flow in which the entire body of fluid within a designated space moves with approximate uniform velocity in one direction along parallel flow lines. Typically occurs when the Reynolds number is less than 2000. Use flow for transporting fluid.

Turbulent flow - the flow in the majority of the pipe is disorderly and chaotic. The molecules are mixing freely and traveling at about the same rate through the diameter of the pipe. A small laminar layer, called the boundary layer, is adjacent to the wall. This type of flow has a high resistance to flow and is not good for transporting fluids. Turbulent flow is desirable for heat transfer applications, as the fluid mixes well and the heat is move even transport away with the bulk of the fluid.

Accumulators

An accumulator is a mechanic storage device designed to store liquid under pressure. The accumulator stores the energy of the pressurized fluid as a source of power. Accumulators can be classified into two main types: Hydropneumatic and Mechanical. Mechanical accumulators use weighted plunger or ram or spring which applies force to liquid via a piston. Hydropneumatic units are the most commonly used. Hydropneumatic accumulators use compressed gas which applies a force to the stored liquid. The accumulator is precharged with pressurized gas. It typically uses air or inert gas. Nitrogen is commonly used as it is inexpensive, easily available, and does not cause corrosion. The gas may come in direct contact with the liquid or may be separated from the liquid by a bladder or piston. Gas is compressible, so that as hydraulic fluid enters the accumulator the gas is compressed. The accumulators operate using Boyles' Law, which states $p_1v_1 = p_2v_2$. The pressure and volume at point 1 are known, if the pressure at 2 increases the volume must decrease proportionally. Accumulator range in standard sizes from 1.5 in^3 to 10 gallon capacity. Pressure in the accumulator can be up to 6000 psi.

Accumulators are used as an auxiliary power source to supplement a smaller pump where the cycle time will allow the pump to pressurize the accumulator charge to peak pressure requirements. Commonly used for systems with intermittent duty requirements. Using an accumulator reduces input horsepower requirements by storing energy during idle times. Additionally accumulators can be used as an emergency power source in case of a power failure to allow operation of critical equipment. The energy stored in the accumulator is available to the system even if there is a loss of electrical power to the primary pump.

Accumulators also serve as a hydraulic shock absorber for circuits where sudden impact loads, quick stops or reversal with heavy loads. For this application the accumulator should be installed as close to shock source as possible. Finally accumulators can be used as a makeup fluid source for applications necessary to maintain a constant fluid pressure to loads for long periods of time. A pressure switch is installed in the system to start and stop pump to maintain pressure adequate to hold force.

The pressure of the gas in the accumulator is selected so that all the hydraulic charge pressure is used to do useful work. The precharge pressure is equal to the minimum pressure necessary to do the work. Sizing of an accumulator is based on amount of hydraulic fluid to be used, with volume based on sum of hydraulic fluid stored and volume of compressed gas necessary to deliver fluid at working pressure.

Basic operation

Oil from a tank or reservoir flows through a pipe into a pump. The pump can be driven by a motor, turbine, or an engine. The pump increases the pressure of the oil. The high pressure oil flows in the piping through a control valve. The control valve changes the direction of the oil flow. A relief valve, set at a desired safe operating pressure, protects the system from an over pressure condition. Oil entering the cylinder applies pressure to the piston, developing a force on the piston rod. The force on the piston rod enables the movement of a load or device. The oil from the other side of the piston returns to a reservoir or a tank via a filter, which removes foreign particles.

Hazards

Any use of a pressurized fluids can be dangerous. Hydraulic systems carry all the hazards of pressurized systems and special hazards that are related directly to the composition of the fluid used. When using oil, the preferred fluid in a hydraulic system, the possibility of a fire or an explosion exists. A severe fire hazard is generated when a break in high pressure piping occurs and oil vaporizes into the atmosphere. Extra precautions against fire should be practiced in these areas.

If oil is pressurized by compressed air, an explosive hazard exists if the high pressure air comes in contact with the oil, because it may create a diesel effect and subsequent explosion. A carefully followed preventive maintenance plan is the best precaution against an explosion.

Pressurized and non-pressurized flow.

When concerned with hydraulic transmission of energy, pressurized and non-pressurized flow must be considered. Energy is transmitted by the fluid from something (pump, accumulator, etc.) to something (actuator, motor, etc.). Non-pressurized flow utilizes only kinetic energy. The actual energy associated with the flow or movement of the fluid and its effect on a components or system. However when dealing with pressurized systems the potential energy and flow energy stored in the pressurized fluid will also be utilized in addition to the kinetic energy. However, when dealing with pressurized flow there generally needs to be an associated system to assist in storing and transferring the energy of the fluid.

Network analysis

A piping network analysis is required for all well designed distribution systems and is comparable to that of utility electric power networks. All of the analysis methods involve the solution of flow problem considering head losses of a complex distribution network resulting in extremely tedious and time consuming trial and error calculations. Computer software does exist today to make this task faster and easier.

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **K&S 1.9-J.1.a.** refer to:
   - Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-6514725-4. Chapter 2 Principles of Hydraulics, Chapter 13 Hydraulic Fluids.
   - Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Introduction; Chapter 1 Basic Principles of Hydraulics;
   - Gunther, Raymond C. (1971). Lubrication. Philadelphia, PA: Chilton Book Company. ISBN 0-8019-5526-2.
   - Westinghouse Savannah River Company High Level Waste Operator Training Heat Transfer and Fluid Flow Study Guide (NWMOG009.H0103) Chapter Fluid Properties; Chapter Fluid Flow Fundamentals.

b. For Supporting Knowledge and Skills **K&S 1.9-J.1.a. and K&S 1.10-K.1.a.** refer to:
   - Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-6514725-4. Chapter 7 Hydraulic Accumulators
   - Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 9 System Components and Circuits.
   - Parker Fluidpower, (1991). Industrial Hydraulic Technology Bulletin 0232-B1. USA: Parker Hannifin Corporation. ISBN 1-55769-000-6.

c. For Supporting Knowledge and Skills **K&S 1.9-J.1.b. and K&S 1.10-K.1.a.** refer to:
   - Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-6514725-4. Chapter 7 Hydraulic Accumulators
   - Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 9 System Components and Circuits.

d. For Supporting Knowledge and Skills **K&S 1.9-J.1.c. and K&S 1.10-K.1.b.** refer to:
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Additional Auxiliary Equipment.
- Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-6514725-4. Chapter 7 Hydraulic Accumulators
- Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 9 System Components and Circuits.

e. For Supporting Knowledge and Skills **K&S 1.9-J.1.d. and K&S 1.10-K.1.f.** refer to:
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Additional Auxiliary Equipment.
- Stewart, Harry L. and Rex Miller (revised) (1991).Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-6514725-4. Chapter 7 Hydraulic Accumulators
- Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 9 System Components and Circuits.

f. For Supporting Knowledge and Skills **K&S 1.9-J.1.e. and K&S 1.10-K.1.c.** refer to:
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Additional Auxiliary Equipment.
- Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-6514725-4. Chapter 7 Hydraulic Accumulators
- Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 9 System Components and Circuits.
- Parker Fluidpower, (1991). Industrial Hydraulic Technology Bulletin 0232-B1. USA: Parker Hannifin Corporation. ISBN 1-55769-000-6.

g. For Supporting Knowledge and Skills **K&S 1.9-J.1.f. and K&S 1.10-K.1.d.** refer to:
- Anders, James E. Sr. (1983). Industrial Hydraulics Troubleshooting. New York, NY: McGraw-Hill Book Company. ISBN 0-07-001592-9.
- Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 9 System Components and Circuits.

h. For Supporting Knowledge and Skills **K&S 1.9-J.1.g.** refer to:
   - Parker Fluidpower, (1991). Industrial Hydraulic Technology Bulletin 0232-B1. USA: Parker Hannifin Corporation. ISBN 1-55769-000-6

i. For Supporting Knowledge and Skills **1.9-J.1.h.** refer to:
   - Nayyar, Mohinder, P.E. (1992). Piping Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8. Part C, Water Systems Piping.

j. For Supporting Knowledge and Skills **K&S 1.10-K.1.e.** refer to:

k. For Supporting Knowledge and Skills **K&S 1.10-K.1.g.** refer to:
   - Anders, James E. Sr. (1983). Industrial Hydraulics Troubleshooting. New York, NY: McGraw-Hill Book Company. ISBN 0-07-001592-9.

4. Practice Exercise
   a. Match the definition in column A with the parameter in column B. Use the column B answers one time only. Ignore any response in column B not identified in column A. (K&S 1.9-J.1.a.) (K&S 1.10-K.1.a.)

Column A	Column B
__ 1. The comparison of weight of a liquid to the weight of an equal volume of water.	a. Dynamic viscosity
__ 2. The volume of a unit mass of a fluid.	b. Kinematic viscosity
__ 3. Deals with the mechanical properties of liquids and their application in engineering systems.	c. Hydraulic
__ 4. The ratio of the shear force and the rate or velocity at which the fluid is being sheared.	d. Pneumatic
	e. Force
	f. Stress
	g. Specific volume
	h. Specific gravity

   b. Select the type of flow represented by smooth layers of fluid sliding on top of each other. (K&S 1.9-J.1.a.) (K&S 1.10-K.1.a.)

      1) Capillarity

      2) Cavitation

      3) Laminar

      4) Turbulent

c. Define the following: (K&S 1.9-J.1.a.) (K&S 1.10-K.1.a.)

Force

Pressure

d. Describe the basic operation of a hydraulic system. (K&S 1.9-J.1.c.) (K&S 1.10-K.1.b.)

e. Discuss the hazards associated with hydraulic systems. (K&S 1.9-J.1.f.) (K&S 1.10-K.1.d.)

f. Which type of energy is of importance in non-pressurized flow? (K&S 1.9-J.1.g.)

1) flow energy

2) kinetic energy

3) potential energy

4) thermal energy

5. Practice Exercise Answers

a. Match the definition in column A with the parameter in column B. Use the column B answers one time only. Ignore any response in column B not identified in column A. (K&S 1.9-J.1.a.) (K&S 1.10-K.1.a.)

Column A	Column B
_h_ 1. The comparison of weight of a liquid to the weight of an equal volume of water.	a. Dynamic viscosity
_g_ 2. The volume of a unit mass of a fluid.	b. Kinematic viscosity
_c_ 3. Deals with the mechanical properties of liquids and their application in engineering systems.	c. Hydraulic
_a_ 4. The ratio of the shear force and the rate or velocity at which the fluid is being sheared.	d. Pneumatic
	e. Force
	f. Stress
	g. Specific volume
	h. Specific gravity

b. Select the type of flow represented by smooth layers of fluid sliding on top of each other. (K&S 1.9-J.1.a.) (K&S 1.10-K.1.a.)

1) Capillarity

2) Cavitation

3) Laminar

4) Turbulent

c. Define the following: (K&S 1.9-J.1.a.) (K&S 1.10-K.1.a.)

- Force — a push or pull against the total area of a surface. It is expressed in pounds force (lbf in English units). The mathematical equation can be represented as F = P x A.

- Pressure — the amount of force on a unit area of the surface. Simply, pressure is the force exerted upon one square inch of a surface (lbf/in^2 in English units). The mathematical equation can be represented as P = F / A.

d. Describe the basic operation of a hydraulic system. (K&S 1.9-J.1.c.) (K&S 1.10-K.1.b.)

Oil from a tank or reservoir flows through a pipe into a pump. The pump can be driven by a motor, turbine, or an engine. The pump increases the pressure of the oil. The high pressure oil flows in the piping through a control valve. The control valve changes the direction of the oil flow. A relief valve, set at a desired safe operating pressure, protects the system from an over pressure condition. Oil entering the cylinder applies pressure to the piston, developing a force on the piston rod. The force on the piston rod enables the movement of a load or device. The oil from the other side of the piston returns to a reservoir or a tank via a filter, which removes foreign particles.

e. Discuss the hazards associated with hydraulic systems. (K&S 1.9-J.1.f.) (K&S 1.10-K.1.d.)

- When using oil, the preferred fluid in a hydraulic system, the possibility of a fire or an explosion exists. A severe fire hazard is generated when a break in high pressure piping occurs and oil vaporizes into the atmosphere.

- An explosive hazard exists if the high pressure air comes in contact with the oil, because it may create a diesel effect and subsequent explosion.

f. Which type of energy is of importance in non-pressurized flow? (K&S 1.9-J.1.g.)

1) flow energy

2) kinetic energy

3) potential energy

4) thermal energy

This page is intentionally blank.

L. **Competency 1.11**

Mechanical system (FAC# 1.18) personnel shall demonstrate a working level knowledge of the principles of lubrication.

1. Supporting Knowledge and Skills

   a. Define:

      - Viscosity
        DOE Fundamentals Handbook Thermodynamics (DOE-HDBK-1012/3-92) Heat Transfer, and Fluid Flow, Volume 3 of 3, Module 3, Fluid Flow, Chapter Laminar and Turbulent Flow
      - Film thickness

   b. Identify and discuss various types of lubricants to include:

      - Oil
      - Water
      - Solids/powders
      - Gaseous
      - Grease

   c. Discuss the Saybolt method of determining viscosity.

   d. Using component vendor data, determine the proper class of lubricant for the component.

   e. Discuss the hazards to equipment associated with mixing different types of oils.

2. Self-Study Information

   Competency 1.11 addresses the familiarity level knowledge of the principles of lubrication.

   The supporting material for the Self-Study Activities include the following documents:

   - DOE Fundamentals Handbook Thermodynamics (DOE-HDBK-1012/3-92) <u>Heat Transfer, and Fluid Flow</u>, Volume 3 of 3.
   - ASTM Standards on Petroleum Products and Lubricants.

- Bureau of Naval Personnel (Revised 1971). Fireman Rate Training Manual (NAVPERS 10520-D). Washington, DC: Training Publications Division. Stock Order No. 0500-137-1010. Chapter 7 Steam Turbines and Reduction Gears.
- Gunther, Raymond C. (1971). Lubrication. Philadelphia, PA: Chilton Book Company. ISBN 0-8019-5526-2.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.
- Neale, M. J. (1993). Lubrication. Oxford, England: Butterworth-Heineman Ltd. ISBN 1-56091-392-4.
- Olberg, Erik, Franklin D. Jones, Holbrook L. Horton, Henry H. Ryffel, Edited by Green Robert E. (1992). Machinery Handbook. New York, NY: Industrial Press Inc. ISBN 0-8311-2492-X.
- Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications.
- Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4.

Viscosity - is the fluid property that measures the resistance of the fluid to deform to a shear force. Viscosity of an oil is its tendency to resist flow or change of shape. Viscosity is a measure of a fluid's resistance to flow. The internal resistance of one layer of fluid moving in relation to another layer of fluid.

Lubricants and hydraulic fluids broken in three categories: petroleum based (oils), synthetic based, and water. Additives are frequently add to improve the characteristics of the lubricating fluid. Typical additives include: anti-foaming, rust inhibitors, film strengthener, and oxidation stabilizers. Additives should only be added by the manufacturer.

Lubrication is necessary to reduce the friction between moving surfaces. This is done to use fluid friction instead of rolling friction or sliding (solid) friction. By using lubrication, several thin layers of fluid exists between the moving surfaces. The two surfaces do not come in contact with one another so sliding friction is prevented. The mass of the moving surfaces create sliding friction with the molecules of the lubricant.

Oil - lubricating oils are derived from crude oil. The oil is refined into varying grades or weights based on the refining method used. Additives can be added to the oil to provide additional capabilities, e.g., corrosion protection, anti foaming, anti fouling, load capacity. Oil is used in components to reduce the amount of friction between to surfaces. Additionally friction generates heat, in lubricated systems the heat can be transferred to the oil. The oil can be passed through a heat exchanger and the heat from friction can be transferred out of the system. The cool oil can be returned to the system.

Synthetics - Some advantages of synthetic lubricants are: generally (but not always) fire resistant, reduced formation of sludge and gums, and changes in temperature do not have as significant affect on the viscosity and thickness of the fluid. The major disadvantages of synthetics are: cost (which is being reduced) and detrimental effects of the fluid on some packing and filter materials.

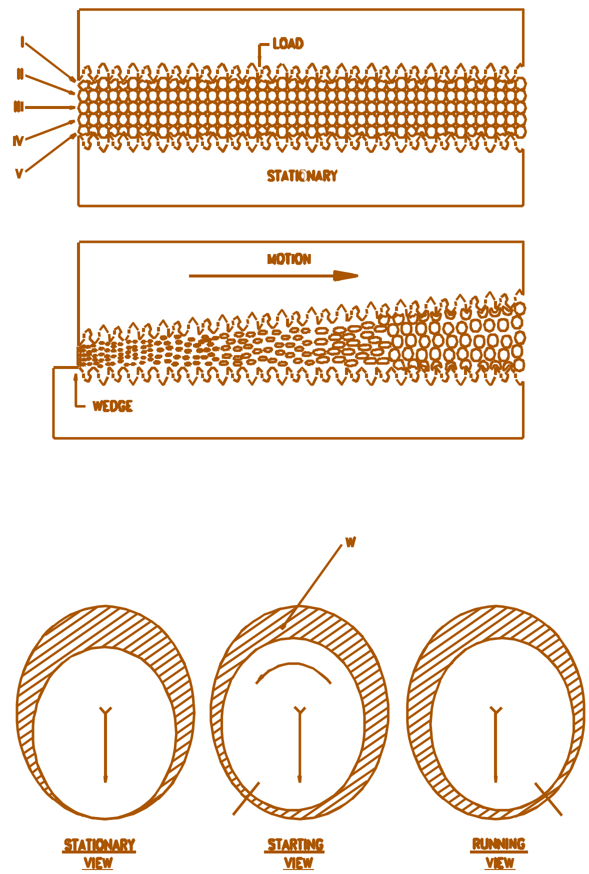


Figure 35 Formation of Lubrication Wedge

Water - infrequently used as a lubricant. Water has good lubricating qualities must generally cannot withstand the high temperature created. The high specific heat property is a benefit to using water as it can transport a large amount of energy and promotes cooling. Used in nuclear reactors where it is important not to introduce impurities to the reactor. When used as a lubricant the bearings have to be made out of a material with high wear resistance. Can be a problem in oil systems because the water can emulsify the oil. The water can cause corrosion of components, increases frictional resistance, or cause the oil film to breakdown.

Powders - or solid lubricants used several ways primarily as additives to oils and greases or in a dry state. Applied as dry solids to metal surfaces for exposure to high temperatures or dusty environments. Some times bonded to the metal as a coating, common in aerospace applications. Added to sintered metals and plastics to provide self lubrication. Application and uses include incompatible environments; extreme temperature and pressure; vacuum conditions; under intermittent loading; where bearing are inaccessible; used for high load, slow speed or oscillating load conditions; and where extreme exposure to nuclear radiation. Designed to reduce friction and wear between metal-to-metal surfaces. Examples of solid lubricants include: graphite, molybdenum disulfide, polytetrafluoroethylene (PTFE), polychlorotrifluoroethylene (PCFE), talc, mica, sulifides of titanium and tungsten, tellurides, and selenides. Properties of solid lubricants include: low shear strength, high elastic-strain limit, excellent adhesion to base surfaces, and good film continuity. Limitations of solid lubricants include: inability to carry away heat; not self replenishing; immobile when bonded to sublayers of metals; and requires careful preparation of surfaces they are applied to, the contacting surfaces should be smooth and flat. To be considered a true lubricant solids must possess the qualities of lubricants where adjacent molecule layers slide across one another.

Gases - Used for high-speed light-load applications. Ultracentrifuges, high speed grinding spindles, gas circulators for nuclear reactors, inertial gyroscopes, dynamometers, electric motors, gas turbines, jet engines, and missiles are possible. Heavier applications include thrust bearings of vertical turbines and rotating mounts of large telescopes. Good potential uses food, textile, and chemical industries where contamination must be avoided. Future applications include cryogenics and space exploration. Example of some gases used for lubrication: air, helium, carbon dioxide, nitrogen, and hydrogen. The most commonly used, as it is readily available, is air. Advantages of gases lubricants include: the coefficient of friction approaches zero and the viscosity is not greatly affected by temperature. Operation based on the same principle used in liquid lubricants, a wedge of gas molecules forms between the surfaces of the bodies in motion. Requires extreme precision in the construction and alignment of bearings. During initial startup external means required to protect the wearing surfaces. Self-aligning bearing required during operation.

Grease - formerly lubricating greases were lubricating oils with additives (soap) to ensure the lubricant stayed in place. Additional additives were included to provide additional capabilities, e.g., graphite, lead, anti oxidizers. Produced under controlled conditions by mixing materials at elevated temperatures. Greases are classified by the thickness, physical properties, or chemical properties. New forms of greases include silicon.

Saybolt method of determining viscosity - measures kinematic viscosity. Kinematic viscosity is the ratio of the shear stress to the rate of shear. A sample of oil is placed in a cylinder with a small diameter hole in the bottom of the cylinder. The temperature of the cylinder and oil is held constant. The time it takes for 60 cubic centimeter of oil to flow out of the cylinder is measured. This is the Saybolt Universal Constant, in seconds. This can be converted to Society of Automotive Engineers (SAE) Numbers. The Table below show the number of seconds for the oil to drain and the corresponding SAE Number.

Saybolt Reading (Seconds)		
Minimum	Maximum	SAE Number
90	<120	10
120	<185	20
185	<225	30

Lubricant selection

Selection of the lubricating fluid should be based on supplying a steady, incompressible flow of oil. The purpose is to provide a layer/film of molecules between the moving parts to reduce friction. It is typically easier for molecules of the lubricating fluid to flow or slide over one another than the molecules of the solid components being separated.

Hazards mixing oils

Contaminants considered any circulating substance other than the oil or its additives. Maybe solid, liquid, or gas. Maybe absorbed from the air: moisture or gas. Example may cause foaming, the formation of an acid, or collect and form water which may emulsify the oil. The formation of acids may form sludges or accelerate corrosion of the system materials. Solids can be abrasive and cause excessive wear. Lubricating oils approved for use ensure proper lubrication under all anticipated operating conditions. Lubricating oils are tested for specific characteristics. The right type of lubricant ensure proper operation of the system. Mixing different types of lubricants can prevent proper lubrication of component resulting in damage to components and systems. It is important to always use the specified lubricant.

Some tips for maintaining purity of lubrication fluids:

- Always store in clean properly labeled containers
- Ensure containers properly closed and sealed
- Store in authorized areas only (also ensures minimal fire/explosion hazards and reduces absorption of moisture)
- Do not mix different types of oils

- Use manufacturer/vendor recommend lubricants
- Transport and transfer in clean approved containers/systems
- Clean system thoroughly before adding oil initially. Do not add large quantities of clean oil to dirty systems
- Check sump levels regularly
- Check oils for contamination (send samples to laboratory/manufacturer for determining nature of contamination)
- Drain and replace oil at regular intervals (based on manufacturer/vendor recommendations, operating conditions and quality of oil)

Potential sources of contamination:

- Wear. The small, microscopic particles of metals and seals caused by the components sliding or wearing on one another or by the flow of fluid across the surface of the material.
- Corrosion. The oxide layer that is created on the surface of the piping and components is not tightly bonded to the surface of the metal. Small pieces can break off and travel in the fluid.
- Sludge/gum/acids. A chemical reaction can affect the structure of the lubricating fluid. The reaction is accelerated under the extreme temperatures and pressures that can be generated between moving surfaces.
- Built in contaminants. This can be metals, lints, or foundry sand from improperly cleaned components and equipment.
- Outside contaminants. External pieces of dirt, lint, and water. These typically occur from improper maintenance and cleanliness.

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills 1.11-L.1.a. refer to:

- Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter 9 Lubrication and Associated Equipment.
- Power. <u>The Engineer's Reference Library</u>. New York, NY: McGraw-Hill Publications. Chapter Lubricants.
- Gunther, Raymond C. (1971). <u>Lubrication</u>. Philadelphia, PA: Chilton Book Company. ISBN 0-8019-5526-2.
- Neale, M. J. (1993). <u>Lubrication</u>. Oxford, England: Butterworth-Heineman Ltd. ISBN 1-56091-392-4.

b. For Supporting Knowledge and Skills 1.11-L.1.b. refer to:
   - Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter 9 Lubrication and Associated Equipment.
   - Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publication. Chapter Lubricants.
   - Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 14 Hydraulic Fluids
   - Gunther, Raymond C. (1971). Lubrication. Philadelphia, PA: Chilton Book Company. ISBN 0-8019-5526-2.
   - Neale, M. J. (1993). Lubrication. Oxford, England: Butterworth-Heineman Ltd. ISBN 1-56091-392-4.
   - Olberg, Erik, Jones, Franklin D., Horton, Holbrook L., Ryffel, Henry H. Edited by Green Robert E. (1992). Machinery Handbook. New York, NY: Industrial Press Inc. ISBN 0-8311-2492-X. Section Lubricants.

c. For Supporting Knowledge and Skills 1.11-L.1.c. refer to:
   - Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publication. Chapter Lubricants.
   - Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 14 Hydraulic Fluids.
   - Bureau of Naval Personnel (Revised 1971). Fireman Rate Training Manual (NAVPERS 10520-D). Washington, DC: Training Publications Division. Stock Order No. 0500-137-1010. Chapter 7 Steam Turbines and Reduction Gears.

d. For Supporting Knowledge and Skills 1.11-L.1.d. refer to:

e. For Supporting Knowledge and Skills 1.11-L.1.e. refer to:
   - Gunther, Raymond C. (1971). Lubrication. Philadelphia, PA: Chilton Book Company. ISBN 0-8019-5526-2.
   - Stewart, Harry L. and Rex Miller (1991 revised). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4. Chapter 13 Hydraulic Fluids

For additional information refer to:
   - ASTM Standards on Petroleum Products and Lubricants.

4. Practice Exercise

   a. The fluid property that measures the resistance of the fluid to deform to a shear force. (K&S 1.11-L.1.a.)

      1. Absolute viscosity
      2. Film thickness
      3. Viscosity
      4. Lubrication

   b. List one application for each of the following lubricants. (K&S 1.11-L.1.b.)

      - Water

      - Solids/powders

      - Gaseous

   c. The Saybolt method of determining viscosity is being used answer the following questions. (K&S 1.11-L.1.c.)

      1. How much sample must be collected?

      2. Why is the water bath temperature held constant?

      3. It takes 120 seconds for the require sample to be collected, what is the SAE number for the lubricant?

   d. List three hazards associated with water in oil. (K&S 1.11-L.1.e.)

5. Practice Exercise Answers

a. The fluid property that measures the resistance of the fluid to deform to a shear force. (K&S 1.11-L.1.a.)

1. Absolute viscosity
2. Film thickness
3. **Viscosity**
4. Lubrication

b. List one application for each of the following lubricants. (K&S 1.11-L.1.b.)

- Water - nuclear reactor coolant pumps
- Solids/powders -
- Gaseous - nuclear gaseous circulators

c. The Saybolt method of determining viscosity is being used answer the following questions. (K&S 1.11-L.1.c.)

1. How many milliliters must be collected?

   60 ml

2. Why is the water bath temperature held constant?

   To ensure the fluid being measured is at a standardized temperature.

3. It takes 120 seconds for the require sample to be collected, what is the SAE number for the lubricant?

   SAE number is 20.

d. List three hazards associated with water in oil. (K&S 1.11-L.1.e.)

Water and oil can form acids which can accelerate the corrosion of the system.

Water and oil can form sludge or gum which can clog small passages.

Water will emulsify the oil which reduces the lubricating capacity of the oil.

This page is intentionally blank.

M. **Competency 1.12**

Construction management and engineering (FAC# 1.24), Facility maintenance management (FAC# 1.5 & 1.7), and Facility representative (FAC# 1.6) personnel shall demonstrate familiarity level knowledge of strainers and filters.

1. Supporting Knowledge and Skills

   a. Discuss the function and application of the following types of filters/strainers used in mechanical fluid flow systems and ventilation systems, including an example of typical use:

   - Cartridge filters
   - Precoated filters
   - Deep-bed filters
   - Particulate filters
   - High Efficiency Particulate (HEPA) filters
   - Bucket strainers
   - Duplex strainers

   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Filters and Strainers, page 40-46.

   b. Describe the difference between bucket and duplex strainers.

   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Filters and Strainers, page 45-46.

   c. Identify and describe the hazards associated with high efficiency particulate filters, including any fire safety concerns.

N. Competency 1.13

Mechanical systems (FAC# 1.10) personnel shall demonstrate a working level knowledge of strainers and filters.

1. Supporting Knowledge and Skills

   a. Compare and contrast the design, operating characteristics, and applications of filters and strainers.

b. Describe the following types of strainers and filters, including an example of typical use for each:

- Electrostatic filters
- Cartridge filters
- Precoated filters
- Deep-bed filters
- High efficiency particulate (HEPA) filters
- Duplex strainers
- Bucket strainers

DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Filters and Strainers, page 40-46.

c. Identify and describe the hazards associated with high efficiency particulate filters, including any fire safety concerns.

d. Discuss how to determine the appropriate high efficiency particulate filter flow.

2. Self-Study Information

Competency 1.12 and 1.13 addresses the construction and operation of strainers and filters. Competency 1.12 at a familiarity level and Competency 1.13 at a working level of knowledge.

The supporting material for the Self-Study Activities include the following documents:

- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101)
- Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 7
- Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 5 Conditioning Power Fluids.
- Underwriters Laboratory (UL) Standard 585, High-Efficiency Particulate Air Filter Units.

Sometimes when discussing filters and strainer one gets a mind set of the system that will be used. Some people think of a system that contains a pump and a liquid (like the oil system in your automobile), while other people think of a fan and a gas (like a ventilation system). A filter or strainer can be installed in either system. The difference is just the medium being cleaned and the material used to do the cleaning.

Another common confusion deals with the similarities and differences between strainers and filters. They both serve the same purpose, that is remove undesirable solid or particles from a fluid stream. Typically one thinks of a strainer performing the rough work removing the larger pieces and the filter doing the finer work or removing the smaller pieces. Pease and Pippenger in <u>Basic Fluid Power</u> page 81 define the differences as follows:

> Strainer - defined "a device for removal of solids from a fluid wherein the resistance to motion of such solids is in a straight line."
>
> Filter - defined "a device for removal of solids from a fluid wherein the resistance to motion of such solids is in a tortuous path."

A strainer generally consists of a fine mesh wire screen or screening element. It doesn't provide fine filtrating thus it offers less resistance to flow. Strainers are commonly in suction lines to remove large debris to prevent damage to pump. The capacity of inlet strainer must be sufficient to prevent a large pressure drop. The finer the mesh the larger the pressure drop. The pressure drop also increases as element becomes clogged or filled. If pressure drop becomes significant enough it may cause starvation and cavitation of the pump.

The filter ratings is usually given in microns (μm). One micron equals one-millionth of a meter or about 0.000039 inches. The human eye is able to detect an object about 40 microns, most detrimental particles not detectable by human eye. The filter rating is given in two parts the Nominal Rating and the Absolute Rating. The nominal rating indicates the ability to remove 98% of the solid particles in the fluid equal to or greater than the micron rating of the filter. The absolute rating indicates the size of the particle that can pass through the filter pores which the fluid must flow through. The absolute gives the largest size particle that could fit though the element. Example a filter may have an absolute rating of 50 μm (micron) and a nominal rating of 25 μm. The large size of 50 μm is the largest size particle that can pass through the pores of the filter. The smaller nominal size of 25 μm come from the fact that although a single 25 μm particle may pass through any single pore in the filter, because of the large number of pores the particle must pass through or the build up of additional particles on the filter medium 98% of the particle 25 μm or larger are removed.

Filters can be classified into two main types: surface (edge) type and depth type. Surface filter accomplishes all filtering on the surface of the media. Pore of uniform size. The filtering action approaches absolute rating. These filters are easy to clean and resists migration of filter media. The filter has a low dirt holding capacity. Depth filters operate throughout the volume of the filter media by presenting many tortuous passages for the fluid to flow through. An example of a depth filter is a sand filter or the filtration that occurs in an ion exchanger. The pores and passage not uniform in size. The particles are removed by entrapment. As the particles attempt to flow through the filter media the varying size pores and tortuous path the particle must travel gradually slows the particle down until it is trapped in the media. The efficiency of the depth filter is based on the on depth of the media and nature of the various passages. Typically used for relatively low flow rates, and low pressure drops.

The filter can be made many different materials. The filter media selected is based on the size and type of particulate to be removed, the fluid being filtered, the operating parameters of the fluid (pressure and flow primarily), and cost. Some common filter media is paper, fiberglass, sintered metal powder, woven wire cloth, ceramics, or plastics. Often paper filter can be treated with resin to provide greater strength. The size of the particle that can be removed depends on the pores, surface area and build up of filter cake. Two common methods of increasing the surface area available for filtration is the concertina or folded filter and the stacking of layers of paper with alternating spacers. Paper filters can effectively remove particles between 2 and 25 micron. Typical paper absolute rating of 5 μm and up, creating nominal ratings between .5 to 100 μm. Paper filters do have some temperature limitations. Paper filters are typically consider surface filters, but dependent on the flow path through the paper may be considered as depth filters.

Sintered metal bronze and stainless steel filters have absolute ratings of 13 to 100 microns and nominal ratings of 2 to 65 micron. Sintering is a heating process where the metal particles are pressurized and heated to a temperature just below the melting point that allows the particles to bond together without form one solid mass. This allows paths through the metal for the fluid to flow. Ceramic and plastic filters typically use many small particles or beads. They are depth type filters. Theses filters have a greater pressure drop encountered and less resistance to thermal and mechanical shock.

Woven wire stainless steel or fiberglass filters have an absolute rating of 12-200 micron and a nominal rating of 2-100 micron. The advantage of this filter medium is a resistance to corrosion and fatigue. These filters are also free from migration filter medium particles that may accompany the ceramic and plastic filter and these filters are not plagued by the problem of penetration by sharp objects that can be associated with paper filters.

Although not strictly a filtering mechanism, magnets are sometimes associated with filters. The magnets are installed in the fluid flow paths and remove magnetic wear and corrosion products.

Strainers and Filters

To remove suspended solids from a liquid, a filter or strainer is necessary. Different filters and strainers are used for different applications. Filters remove the small solids, and strainers remove the large solids. Filters and strainers are used in hydraulic systems, cooling systems, liquid waste systems, water purification, and reactor systems.

Cartridge filters are shaped like cylinders that usually consist of a yarn fiber wound around a perforated metal core. The liquid being filtered is forced through the yarn and then through the perforations in the metal core to the filter outlet. This type of filter is used to remove fine particles. Cartridge filters are inexpensive and easy to replace.

Precoat filters consist of a filter housing that contains vertical tubes on which the medium is deposited. The filtering medium fibers may be made of finely divided diatomite, perlite, asbestos, or cellulose. Diatomite is the least expensive medium and is used to filter liquid waste that is discharged from a facility. Cellulose is usually used for processing water that will be returned to a reactor.

Deep-bed filters are based on a support screen mounted a few inches above the bottom of a tank. The screen is perforated to allow water to flow through it. A coarse aggregate layer of crushed rock or large pieces of charcoal is placed on the screen. This type of filter is used in raw water treatment.

<u>Strainers</u>

Strainers are fitted in many piping lines to prevent the passage of grit, scale, dirt, and other foreign matter, which could obstruct pump suction valves, throttle valves, or other machinery parts. One of the simplest and most common types of strainers found in piping systems is the Y-strainer, which is illustrated in ?.

A **bucket strainer** is simply a bucket to catch debris. The bucket can be removed for cleaning by loosening screws, removing the cover, and removing the bucket by the handle. A bucket strainer is used in systems that is expected to have large debris.

A **duplex strainer** is a strainer consisting of two sides with a basket in each side. Only one side is placed in service at a time. A duplex strainer is usually used in fuel oil and lubricating oil lines where it is necessary to maintain uninterrupted flow of oil. The flow may be rerouted from on basket to another while one basket is being cleaned.

Electrostatic filters

The filter is charged with a small electric charge. Material flowing through the system is electrostatically attracted to the filter. This filter is used for remove dust in some applications. It can also be used in systems with radioactive material, where charged fission product fragments can be attracted to the filter and removed.

High Efficiency Particulate (HEPA) filters

Filters are used to remove particles from the air to maintain the cleanliness of surrounding environment. The advantages of clean air in the surroundings is employee health, productivity, and safety. In the filtration of nuclear systems High Efficiency Particulate Air (HEPA) filters are used for filtration. HEPA filters are designed and tested to remove 99.97% of air particles down to the sub-micron level. The most important feature of HEPA filters is their ability to filter air containing radioactive nuclides suspended in the air. As with all filter medians, it is necessary to be aware of the potential hazard associated with damaged or clogged filters. Clogged filters may result in inefficient filtering and could lead to a potential fire hazard. HEPA filters require monitoring to assure that a fire hazard is not present.

HEPA filter hazards

HEPA filters have many different applications from personal protection on a half or full face respirator to a large ventilation filter for a glove box, room, or building. It should be noted that there are several hazards associated with the use of HEPA filters that should be kept in mind to ensure safe use and operation.

HEPA Filter flow rate - HEPA filters must meet the stated flow rates for the filter and application in which it is being used. If filters with insufficient flow ratings are used it may cause a rupture of the filter or it may not be as efficient as stated within the specifications of the filter. This will cause break through and allow contaminants through the filter at an unacceptable level.

Rough handling - Care must be take to ensure that HEPA filters are handled with care to ensure they are not damaged during handling or installation. Damage may result in leakage or rupture of the filter causing unacceptable levels of contaminant to pass through the filter. Additionally, if rough handling occurs during change out of the filter it could cause the release of contaminants and exposure of the person changing out the filter.

Fire - A fire could occur in a HEPA filter due to the buildup of radionuclides. A large concentration of radionuclides could cause a fire if the decay heat is not removed. This has been observed in HEPA filters installed in Offgas systems. Current filter requirements are set on fire tests and resistance to fire for HEPA filters.

Frames - It is important not to use HEPA filters with wooden frames in systems with a high moisture content. The moisture may cause a rotting of the frame and cause it to break up and cause the filter to fall apart during removal or dismantling.

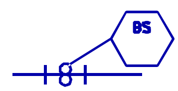
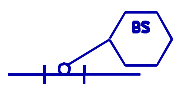
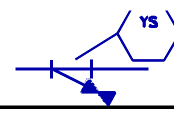
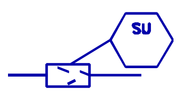
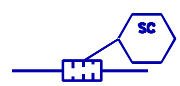
HEPA filters flowrates - HEPA filters must be tested to ensure that they meet their design flow rates. Every filter need not be tested, but a random testing policy must be established to verify that given number of filters per lot meet flow requirements. Each site must establish specific procedures for testing filters. These tests are developed based upon the type of equipment they have to perform the tests and the type filter being tested. The flow rates to be reached are based upon the brand, type, and application for the filter to be tested.

When selecting a filter several factors must be evaluated. Key among them are:

- operating characteristics of system
  - ■ shock
  - ■ fluid velocity
  - ■ stability of flow direction
  - ■ flow rate desired
  - ■ pressure drop will occur across the filter
  - ■ pressure of the system
- capacity of the filter
- physical nature of material to be removed
  - ■ analyze the material used in system fabrication
  - ■ material before and after the filter
    - * seals
    - * fittings
    - * piping, tubing, and hoses
    - * instrumentation
- size of material to be removed the degree of filtration required
  - ■ take into consideration the tolerance of system component that requires the closest tolerance
- compatibility with the properties of fluid being pumped
  - ■ viscosity
  - ■ density
  - ■ operating temperature
  - ■ corrosive nature
- ease of service
- cost

Locating the filter is also important. The filter maybe placed in several places in the system to be filtered depending on the needs of the system. The filter may be place in the sump or reservoir or suction line. Proper sizing of the filter is important, if the filter capacity is to small the pump maybe starved and undergo cavitation. The capacity of a suction side filter should be twice the desired capacity of the line. Filters are placed here to remove particles and debris before it enters the pump. Another common location of a filter is in the discharge of the pump. Again the filter capacity should be twice the desire capacity for the line. The filtration that occurs here is remove particles prior to the fluid entering The large capacity of a discharge filter is so that a clogged filter will not create a back pressure on the pump. The filter can also be located in the bypass line. This location allows a small continuous flow of oil to be continuously filter. Tapping off the discharge side of the pump the recirculation line allows a small amount of flow to return to the sump. If components downstream of the pump have a smaller clearance than the pump often times the filter is installed on the discharge of the pump. This allows smaller particles to be removed with the high pressure developed by the pump. With proper sizing of the pump and filter a large pressure drop can occur across the filter and still maintain adequate flow to the system and components. A filter in the downstream side typically needs a much larger capacity (up to 5 times) to allow the small particles to be removed and still supply the system adequately.

Figure 36 FILTERS AND STRAINERS

Filter		Twin Basket Strainer	
Single Basket Strainer		Y-type strainer	
Temporary startup strainer		Screen type strainer	

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **1.12-M.1.a**, **1.13-N.1.a**, and **1.13-N.1.b** refer to:

- Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4. Chapter 5 Conditioning Power Fluids.
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Filter and Strainers.
- Director, Office of Nuclear Safety, (1994). Safety Notice High-Efficiency Particulate Air Filters. Washington, DC: U.S. Department of Energy.

- Underwriters Laboratories Inc. (1990). Standard for Safety - High-Efficiency, Particulate, Air Filter Units. Northbrook, IL: Underwriters Laboratories Inc. ISBN 1-55989-129-7.

b. For Supporting Knowledge and Skills **1.12-M.1.b** refer to
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Filter and Strainers.

c. For Supporting Knowledge and Skills **1.12-M.1.c** and **1.13-N.1.c** refer to
   - Director, Office of Nuclear Safety, (1994). Safety Notice High-Efficiency Particulate Air Filters. Washington, DC: U.S. Department of Energy.
   - Underwriters Laboratories Inc. (1990). Standard for Safety - High-Efficiency, Particulate, Air Filter Units. Northbrook, IL: Underwriters Laboratories Inc. ISBN 1-55989-129-7.

d. For Supporting Knowledge and Skills **1.13-N.1.d** refer to
   - Facility Representative Advanced Nuclear Course (FRANC), Module 7, Mechanical Systems and Components, chapter Ventilation Fundamentals
   - Underwriters Laboratory (UL) Standard 585, High-Efficiency Particulate Air Filter Units.
   - Director, Office of Nuclear Safety, (1994), Safety Notice High-Efficiency Particulate Air Filters, Washington, DC, U.S. Department of Energy
   - Underwriters Laboratories Inc. (1990). Standard for Safety - High-Efficiency, Particulate, Air Filter Units. Northbrook, IL: Underwriters Laboratories Inc. ISBN 1-55989-129-7.
   - U.S. Department of Energy (1990). Nuclear Standard, Quality Assurance Testing of HEPA Filters. Oakridge, TN: U.S. Department of Energy Office of Scientific and Technical Information.

4. Practice Exercise

   a. This device is used to remove extremely small particles with a very high rate? (K&S 1.12-M.1.a.) (K&S 1.13-N.1.b.)

      1) Cartridge filters

      2) Deep-bed filters

      3) High Efficiency Particulate (HEPA) filters

      4) Precoated filters

   b. This type of filter is self-contained and easy to change, but supply system must keep many different kinds on hand. (K&S 1.12-M.1.a.) (K&S 1.13-N.1.b.)

      1) Cartridge filters

      2) Deep-bed filters

      3) High Efficiency Particulate (HEPA) filters

      4) Precoated filters

   c. Describe the difference between bucket and duplex strainers. (K&S 1.12-M.1.b.)

      Bucket strainer -

      Duplex strainer -

d. Why are HEPA filters in radioactive systems susceptible to fire? (K&S 1.12-M.1.c.) (K&S 1.13-N.1.c.)

e. Complete the table below comparing operating characteristics, and applications of filters and strainers. (K&S 1.13-N.1.a.)

Device	Method of Operation	Particle Size Removed
	removes solids from a fluid by resistance of flow in a straight line	
Filter		

5. Practice Exercise Answers

   a. This device is used to remove extremely small particles with a very high rate? (K&S 1.12-M.1.a.) (K&S 1.13-N.1.b.)

      1) Cartridge filters

      2) Deep-bed filters

      3) High Efficiency Particulate (HEPA) filters

      4) Precoated filters

   b. This type of filter is self-contained and easy to change, but supply system must keep many different kinds on hand. (K&S 1.12-M.1.a.) (K&S 1.13-N.1.b.)

      1) Cartridge filters

      2) Deep-bed filters

      3) High Efficiency Particulate (HEPA) filters

      4) Precoated filters

   c. Describe the difference between bucket and duplex strainers. (K&S 1.12-M.1.b.)

      Bucket strainer - is simply a bucket type device to catch debris. The bucket is in a container or shell. The fluid and debris flow into the bucket. The debris settles to the bottom and the fluid flows up and out of the bucket into the shell and downstream supplying the system. Sometimes the bucket has holes in it and the fluid flows through the holes. This strainer can be removed for cleaning by securing the system or filter, loosening screws, removing the cover, and removing the bucket by the handle. A bucket strainer is used in systems that is expected to have large debris. Often installed in the suction lines of pumps.

      Duplex strainer - is a strainer consisting of two sides with a basket in each side. Only one side is placed in service at a time. A duplex strainer is usually used in fuel oil and lubricating oil lines where it is necessary to maintain uninterrupted flow of oil. The flow may be rerouted from on basket to another while one basket is being cleaned.

d. Why are HEPA filters in radioactive systems susceptible to fire? (K&S 1.12-M.1.c.) (K&S 1.13-N.1.c.)

   HEPA filters can remove a large amount of radionuclides. If the decay heat from the radioactive material is not removed the filter can over heat and catch fire.

e. Complete the table below comparing operating characteristics, and applications of filters and strainers. (K&S 1.13-N.1.a.)

Device	Method of Operation	Particle Size Removed
Strainer	removes solids from a fluid by resistance of flow in a straight line	larger particles
Filter	uses tortuous path for removal of solids from a fluid	small particles

This page is intentionally blank.

O. **Competency 1.14**

Construction management and engineering (FAC# 1.24), EH Residents (FAC# 1.3), Facility maintenance management (FAC# 1.5), Facility representatives (FAC# 1.3), and Instrumentation and control (FAC# 1.17) personnel shall demonstrate familiarity level knowledge of heat exchanger construction, operations, and theory.

1. Supporting Knowledge and Skills

a. Describe the construction and principles of operation for the following types of heat exchangers:

- Shell and tube
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Types of Heat Exchangers.
- Plate type
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Types of Heat Exchangers.
- Fin and tube
- Cooling tower
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Cooling Towers.

b. Define the following terms and given a cutaway drawing of the following types of heat exchangers, show the flow paths of the cooling medium and the medium to be cooled:

- Parallel flow
- Counter flow
- Cross flow

DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Types of Heat Exchangers.

c. Discuss the following heat exchanger applications:

- Air conditioner condenser
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Heat Exchanger Applications.
- Air conditioner evaporator
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Heat Exchanger Applications.

- Cooling tower
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 2 of 2, Module 5, Chapter Cooling Towers.
- Preheater
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Heat Exchanger Applications.
- Radiator
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Heat Exchanger Applications.

P. Competency 1.15

Mechanical systems (FAC# 1.7) personnel shall demonstrate a working level knowledge of the construction and operation of heat exchangers.

1. Supporting Knowledge and Skills

a. Describe the principle of operation for the following types of heat exchangers:

- Shell and tube
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Types of Heat Exchangers.
- Plate type
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Types of Heat Exchangers.
- Fin and tube
- Cooling tower
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Cooling Towers.

b. Define the following terms as they apply to heat exchangers:

- Tube sheet
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Types of Heat Exchangers.

c. Define the following terms and using a cutaway drawing of the following types of heat exchangers, show the flow paths of the cooling medium and the medium to be cooled:

- Parallel flow
- Counter flow
- Cross flow

DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 2, Chapter Types of Heat Exchangers.

d. Compare and contrast the following methods of tube to tube sheet connections:

e. Explain the principle of operation of a forced-draft cooling tower.
DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Cooling Towers.

f. Explain the principle of operation of a natural-draft (parabolic) cooling tower.
DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Cooling Towers.

g. Explain advantages and disadvantages of down-draft versus cross-flow cooling towers.
DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Chapter Cooling Towers.

2. Self-Study Information

Competency 1.14 and 1.15 addresses heat exchanger construction, theory, and purpose. Competency 1.14 at a familiarity level and Competency 1.15 at a working level of knowledge.

The supporting material for the Self-Study Activities include the following documents:

- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2
- Westinghouse Savannah River Company Core Fundamentals Training Program Student Text Mechanical Science Level A Student Text (TTFGMS1A.H0101)
- Westinghouse Savannah River Company High Level Waste Operator Training Heat Transfer and Fluid Flow Study Guide (NWMOG009.H0103)

- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102)
- Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 106
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.
- Parker, Sybil P. (1993). McGraw-Hill Encyclopedia of Engineering. New York, NY: McGraw-Hill, Inc. ISBN 0-07-051392-9.
- Saunders, E. A. D. (1988). Heat Exchangers: Selection, Design and Construction. Essex, England: Longman Scientific & Technical. ISBN 0-470-20870-8.

Fin and tube type heat exchanger - is a variation on a shell and tube type heat exchanger. The construction of this type heat exchanger is that fluid flow through a series of tubes. To increase the heat transfer capability of the heat exchanger a large number of thin fins are attached to the surface area of the tubes. The high temperature fluid flowing through the tubes gives up heat to the surface of the tubes. Conduction then transfers the heat from the tubes to the fins. The large surface area of the fins allows the heat to be transferred to the cooling medium, typically air. A common example of a fin and tube heat exchanger is the radiator in a car or the evaporator on the refrigeration unit of a refrigerator.

Advantages and Disadvantages of Cross-flow vs. Down draft Cooling Towers

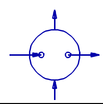
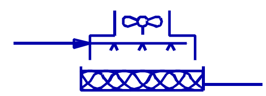
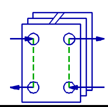
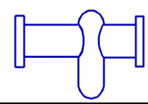
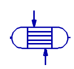
Cooling towers are designed to act as heat exchangers utilizing the atmosphere as the cooling medium. There are two basic types of cooling towers. Evaporative and Non-evaporative cooling towers. In the evaporative cooling tower the warmer water is brought into direct contact with the cooler air. The cooler air is generally at less that saturation and therefore allows for evaporative heat exchange from the water to the air. In the Non-evaporative process the water is normally run through tubes or pipes and air flows across the tubes and heat is transferred via sensible heat transfer.

In either of these types of cooling towers there can be a natural or forced draft cooling. The natural draft works on the principle of warmer air rises and is replaced by cooler air. As the air rises and flows through the water or past the tubes the cooling process occurs. In a forced or mechanical draft cooling tower fans are included to force air flow in a specific direction or control the amount of air flow in the system.

In any cooling tower air flow must occur. The air flow is classified in its relation to the water flow. The air flow can be in parallel, counter, or cross flow. Downdraft cooling towers are mechanical draft towers where the air flow is taken from the top of the cooling tower and forced down through the cooling tower parallel with the waterflow. This is advantageous because is minimizes the evaporative process. Less water is lost due to evaporation, thereby requiring less makeup water. Also in severe cold weather it helps to eliminate icing that can occur on the inside of the cooling tower, fan components, and precipitation that can occur around the cooling tower as a direct result of the cooling tower and environmental conditions.

Cross flow cooling towers can be natural draft or forced draft towers. The towers bring air from the outside edges of the tower and draw it across the water flow or cooling tubes. This is an advantage when there are restrictions or difficulties with a tall tower. The cross flow allows for a very short tower but does require a large ground surface area to ensure there is sufficient area for the air to contact the water or cooling tubes.

Figure 37 HEAT EXCHANGER SYMBOLS

Shell and tube heat exchanger		Cooling tower	
Plate type heat exchanger		Aftercooler with moisture separator	
Cooler or condenser			

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **K&S 1.14-O.1.a. and K&S 1.15-P.1.a.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Student Text Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Heat Exchangers
   - Westinghouse Savannah River Company High Level Waste Operator Training Study Guide Heat Transfer and Fluid Flow (NWMOG009.H0103) Chapter Heat Exchangers.
   - Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter 8 Heat Exchangers and Air Ejectors.

   - Saunders, E. A. D. (1988). <u>Heat Exchangers: Selection, Design and Construction</u>. Essex, England: Longman Scientific & Technical. ISBN 0-470-20870-8.

b. For Supporting Knowledge and Skills **K&S 1.14-O.1.b. and K&S 1.15-P.1.c.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Student Text Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Heat Exchangers.
- Westinghouse Savannah River Company High Level Waste Operator Training Study Guide Heat Transfer and Fluid Flow (NWMOG009.H0103) Chapter Heat Exchangers

c. For Supporting Knowledge and Skills **K&S 1.14-O.1.c.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Student Text Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Heat Exchangers
- Westinghouse Savannah River Company High Level Waste Operator Training Study Guide Heat Transfer and Fluid Flow (NWMOG009.H0103) Chapter Heat Exchangers
- Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter 8 Heat Exchangers and Air Ejectors.

d. For Supporting Knowledge and Skills **K&S 1.15-P.1.b.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Student Text Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Heat Exchangers.
- Westinghouse Savannah River Company High Level Waste Operator Training Study Guide Heat Transfer and Fluid Flow (NWMOG009.H0103) Chapter Heat Exchangers
- Saunders, E. A. D. (1988). <u>Heat Exchangers: Selection, Design and Construction</u>. Essex, England: Longman Scientific & Technical. ISBN 0-470-20870-8.

f. For Supporting Knowledge and Skills **K&S 1.15-P.1.e.** refer to:
- Parker, Sybil P. (1993). <u>McGraw-Hill Encyclopedia of Engineering</u>. New York, NY: McGraw-Hill, Inc. ISBN 0-07-051392-9. Cooling Towers.

g. For Supporting Knowledge and Skills **K&S 1.15-P.1.f.** refer to:
   - Parker, Sybil P. (1993). McGraw-Hill Encyclopedia of Engineering. New York, NY: McGraw-Hill, Inc. ISBN 0-07-051392-9. Cooling Towers.

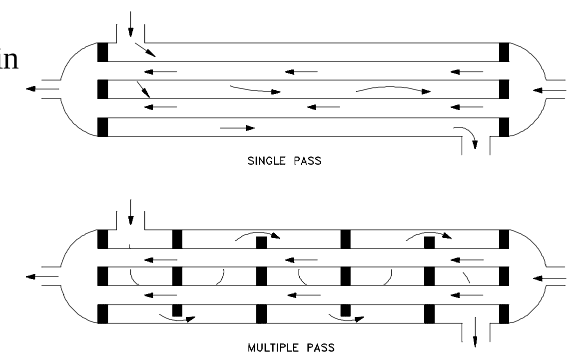
h. For Supporting Knowledge and Skills **K&S 1.15-P.1.g.** refer to:
   - Parker, Sybil P. (1993). McGraw-Hill Encyclopedia of Engineering. New York, NY: McGraw-Hill, Inc. ISBN 0-07-051392-9. Cooling Towers.

4. Practice Exercise

   a. Describe principle of operation for a plate type heat exchangers. (K&S 1.14-O.1.a.) (K&S 1.15-P.1.a.)

   b. What is the purpose of the fins on a fin and tube type of heat exchangers. (K&S 1.14-O.1.a.) (K&S 1.15-P.1.a.)

   c. Refer to the drawing at the right. State the name **AND** purposes of the four (4) main parts of the heat exchanger. (K&S 1.14-O.1.a.) (K&S 1.15-P.1.a.)



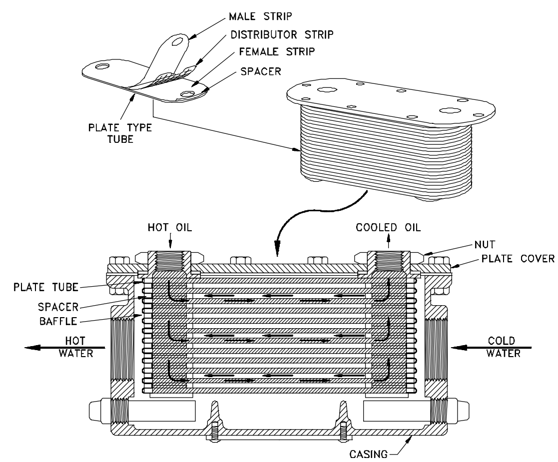
      1.

      2.

      3.

      4.

d. Refer to the drawing at the right. State two (2) advantages and two (2) disadvantages of the heat exchanger. (K&S 1.14-O.1.a.) (K&S 1.15-P.1.a.)



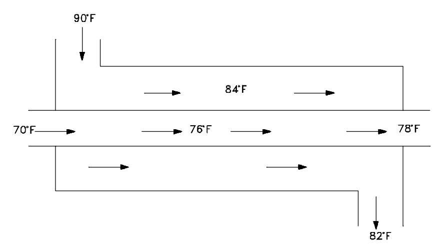
Advantages
1.

2.

Disadvantages
1.

2.

e. Refer to the drawing at the right. Classify the heat exchanger based on the fluid flow paths. (K&S 1.14-O.1.b.) (K&S 1.15-P.1.c.)



f. Classify the heat exchanger based on the temperatures of the fluid flow paths below. (K&S 1.14-O.1.b.) (K&S 1.15-P.1.c.)

T hot in - 120°F   T hot out - 100°F
T cold in - 70°F   T cold out - 105°F

g. List four (4) functions of a heat exchanger and give an example of each. (K&S 1.14-O.1.c.)

1.
   Example -

2.
   Example -

3.
   Example -

4.
   Example -

h. Describe the operation of a **RADIATOR**. (K&S 1.14-O.1.c.)

i. Describe the operation of an **AIR CONDITIONING CONDENSER**. (K&S 1.14-O.1.c.)

j. Which type of cooling tower uses electric fans mounted on top of the cooling tower? (K&S 1.15-P.1.e.)

1) Counter-flow

2) Induced-draft

3) Forced-draft

4) Inverse-draft

k. Explain the principle of operation of a natural-draft cooling tower. (K&S 1.15-P.1.f.)

5. Practice Exercise Answers

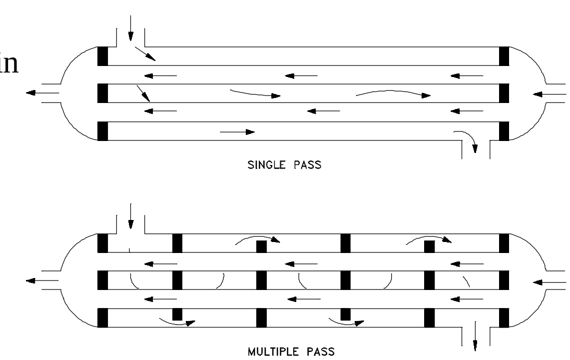
   a. Describe principle of operation for a plate type heat exchangers. (K&S 1.14-O.1.a.) (K&S 1.15-P.1.a.)

      Plate type heat exchangers consists of large surface area plates separating the hot and cold fluids. The hot and cold fluids are directed between alternate spaces between the plates. The heat is transferred from the high temperature fluid by convection and conduction to the metal plate. Conduction then transfers the heat across the metal plate. Finally convection and conduction transfer the heat into the cooler fluid. The large surface area of the plates provide a larger area for the heat transfer to occur. And the thinner plates allow better heat transfer. As a result, a plate type heat exchanger is capable of transferring much more heat than a similarly sized shell and tube heat exchanger.

   b. What is the purpose of the fins on a fin and tube type of heat exchangers. (K&S 1.14-O.1.a.) (K&S 1.15-P.1.a.)

      The large area of the fin increases the effective surface area, thereby increasing the amount of heat transfer that can occur.

   c. Refer to the drawing at the right. State the name **AND** purposes of the four (4) main parts of the heat exchanger. (K&S 1.14-O.1.a.) (K&S 1.15-P.1.a.)



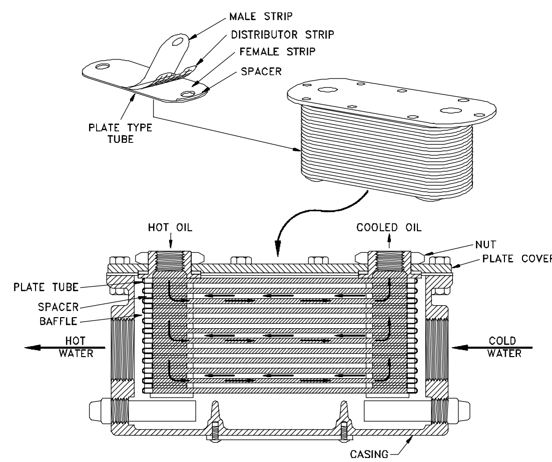
      1. Shell - provides outside boundary for fluid flowing on the outside of the tubes.

      2. Tube - provides flowpath for one fluid (normally the high pressure fluid).

      3. Tube sheet - Provides pressure boundary between and separates tube side fluid and shell side fluid at ends.

      4. Baffle or support plate - provides support of tubes and redirects flow around outside of tubes promotes mixing and turbulence which is better for heat transfer.

d. Refer to the drawing at the right. State the advantages and disadvantages of the heat exchanger. (K&S 1.14-O.1.a.) (K&S 1.15-P.1.a.)



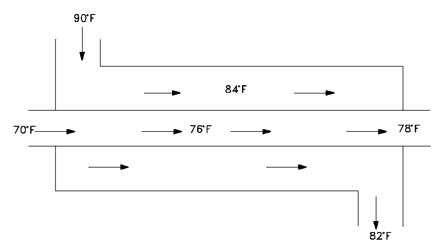
Advantages

- Large surface area better heat transfer capabilities
- Thin wall better heat transfer capabilities
- Easy maintenance and cleaning

Disadvantages

- Difficulty maintaining pressure because of large gaskets required
- Good only for low pressure applications

e. Refer to the drawing at the right. Classify the heat exchanger based on the fluid flow paths. (K&S 1.14-O.1.b.) (K&S 1.15-P.1.c.)



Parallel flow

f. Classify the heat exchanger based on the temperatures of the fluid flow paths below. (K&S 1.14-O.1.b.) (K&S 1.15-P.1.c.)

T hot in - 120°F   T hot out - 100°F
T cold in - 70°F   T cold out - 105°F

Counter flow

g. List four (4) functions of a heat exchanger and give an example of each. (K&S 1.14-O.1.c.)

- To heat a cooler fluid
  Example - house radiator or car heater

- To cool a hotter fluid
  Example - car radiator or air conditioner

- To produce a vapor
  Example - steam generator or air conditioner evaporator

- To condense a vapor
  Example - steam condenser or air conditioner condenser

- To produce a vapor and condense a vapor at the same time
  Example - steam generator

h. Describe the operation of a **RADIATOR**. (K&S 1.14-O.1.c.)

A radiator is a liquid to air heat exchanger. The coolant flowing in and through the heat source (commonly an engine) absorbs heat and carries it to the radiator. In the radiator the hot coolant flows into the tube side of the radiator. The relatively cool air flowing over the outside of the tubes absorbs heat from the coolant thus reducing the temperature of the coolant.

i. Describe the operation of an **AIR CONDITIONING CONDENSER**. (K&S 1.14-O.1.c.)

An air conditioner condenser is a type of heat exchangers contained in all air conditioning systems. The hot, high pressure refrigerant gas, from the compressor, flows into the condenser. As the refrigerant flows into the heat exchanger the refrigerant transfers heat to the cooling medium. Usually the cooling medium is water or air. The low temperature air or water in the condenser absorbs heat from the refrigerant. The refrigerant gives up heat and undergoes a phase change to a subcooled liquid.

j. Which type of cooling tower uses electric fans mounted on top of the cooling tower? (K&S 1.15-P.1.e.)

   1) Counter-flow
   2) Induced-draft
   3) Forced-draft
   4) Inverse-draft

k. Explain the principle of operation of a natural-draft cooling tower. (K&S 1.15-P.1.f.)

   Natural draft cooling towers functions on the principle that hot air rises. As the air inside the tower is heated, it rises through the tower. This process draws more air in, creating a natural air flow to provide cooling of the water.

This page is intentionally blank.

Q. **Competency 1.16**

Construction maintenance and engineering (FAC# 1.24), Facility maintenance management (FAC# 1.4 & 1.7), Facility representatives (FAC# 1.7), Instrumentation and control (FAC# 1.17), Nuclear safety system (FAC# 1.9), and Project management (FAC# 1.1) personnel shall demonstrate familiarity level knowledge of the basic construction, operation, and theory of heating, ventilation, and air conditioning (HVAC) systems.

1. Supporting Knowledge and Skills

   a. Discuss the construction, function, and operation of the components of a Heating, Ventilation, and Air Conditioning (HVAC) system including given a one-line diagram of an HVAC system identify and discuss the following components:

      - Compressors
      - Blowers
      - Dampers
      - Heat exchangers
      - Chillers
      - Filters
      - Scrubbers
      - Hoods
      - Glove Boxes
      - Pressure sensors
      - Hot Cells
      - Confinement systems

   b. Discuss the relationships between the following in HVAC systems:

      - Supply Ventilation
      - Flow
      - Exhaust Ventilation

   c. Identify and discuss when maintaining a negative pressure in an heating, ventilation and air conditioning system is desirable.

   d. Discuss the reason for and safety significance of the following system parameters:

      - Positive vs. Negative system pressure
      - Differential pressure across filters
      - Differential pressure across components

e. Discuss the potential hazards (to equipment and personnel) associated with the use of heating, ventilation, and air conditioning systems and components within nuclear safety-related systems.

f. Describe the purpose, basic design, and operation of a typical heating, ventilation, and air conditioning (HVAC) system including a discussion of the control system used to maintain habitability.

g. Discuss the construction, function, and operation of the components of a basic refrigeration system including given a diagram of the basic refrigeration cycle, discuss the theory of operation of refrigeration systems.

- Compressors
- Receiver
- Condensers
- Thermal expansion valve/Metering device/orifice
- Evaporators

h. Define the following terms as they apply to air conditioning and refrigeration systems:

- Latent heat of vaporization
- Latent heat of fusion
- Refrigerant
- Vaporization point
- Air and non-condensible gases

i. Describe the types of refrigerants used in air conditioning systems.

j. Discuss the hazards associated with these refrigerants.

R. Competency 1.17

EH Residents (FAC# 1.6) and Mechanical systems (FAC# 1.5 & 1.11) personnel shall demonstrate a working level knowledge of the basic construction, operation, and theory of heating, ventilation, and air conditioning systems (HVAC).

1. Supporting Knowledge and Skills

a. Discuss the construction, function, and operation of the components of a Heating, Ventilation, and Air Conditioning (HVAC) system including given a one-line diagram of an HVAC system identify and discuss the following components:

- Compressors
- Blowers
- Dampers
- Heat exchangers
- Chillers
- Filters
- Scrubbers
- Hoods
- Glove Boxes
- Pressure sensors
- Hot Cells
- Confinement systems

b. Discuss the relationships between the following in heating, ventilation, and air conditioning systems:

- Supply ventilation
- Flow
- Exhaust ventilation

c. Compare and contrast the design, operation, and application of axial-flow and radial-flow fans.

d. Identify and discuss when maintaining a negative heating, ventilation, and air conditioning system pressure is desirable.

e. Describe the use of heating, ventilation, and air conditioning in controlling the spread of hazardous material and radioactive contamination.

f. Describe the application and use of heating, ventilation, and air conditioning as an Engineered Safety Feature.

g. Discuss the construction, function, and operation of the components of a basic refrigeration system including given a diagram of the basic refrigeration cycle, discuss the theory of operation of refrigeration systems.

- Compressor
- Condenser
- Thermal expansion valve
- Evaporator coils
- Receiver

h. Compare and contrast the principles of operation for centrifugal and reciprocating refrigeration compressors.

i. Using a cutaway drawing of a typical thermal expansion valve and sensing bulb, explain its principle of operation.

j. Define the following terms as they apply to air conditioning and refrigeration systems:

   - Latent heat of vaporization
   - Latent heat of fusion
   - Refrigerant
   - Vaporization point
   - Air and non-condensable gases

k. Discuss refrigerant leak detection.

l. Discuss the general hazards involved in handling refrigerants.

2. Self-Study Information

Competency 1.16 and 1.17 address the knowledge of basic Heating Ventilation and Air Conditioning (HVAC) system construction and operation. Competency 1.16 at a familiarity level and Competency 1.17 at a working level of knowledge.

The supporting material for the Self-Study Activities include the following documents:

- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2
- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2
- Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 7
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102)
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100)
- Westinghouse Savannah River Company High Level Waste Operator Training Heat Transfer and Fluid Flow Study Guide (NWMOG009.H0102)
- American National Standards Institute (ANSI) B79.1.
- American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 34-67.

- American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. (1980). ASHRAE Handbook and Product Directory, 1977 Fundamentals. New York, NY: American Society of Heating, Refrigeration and Air-Conditioning Engineers.
- American Society of Heating, Refrigeration and Air-conditioning Engineers, (1990). ASHRAE HANDBOOK Refrigeration Systems and Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
- American Society of Heating, Refrigeration and Air-conditioning Engineers, (1991). ASHRAE HANDBOOK HVAC Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
- American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc, (1992). ASHRAE Handbook and Product Directory, 1992 HVAC Systems and Equipment. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers. ISBN 0-910110-87-5.
- American Society of Heating, Refrigeration and Air-conditioning Engineers, (1992). ASHRAE HANDBOOK HVAC Systems and Equipment. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
- American Society of Heating, Refrigeration and Air-conditioning Engineers, (1993). ASHRAE HANDBOOK Fundamentals. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
- Brumbaugh, James E. (1983). Heating, Ventilating and Air Conditioning Library Volume 3. Indianapolis, IN: Bobbs Merrill Company, Inc. ISBN 0-672-23383-5.
- Bureau of Naval Personnel (revised 1969). Refrigeration and Air Conditioning (NAVPERS 16163-A). Stock Ordering No. 0502-LP-080-8150.
- Gollnick, Daniel A., (1994). Basic Radiation Protection Technology Third Edition. Altadena, CA: Pacific Radiation Corporation.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.
- Underwriters Laboratories Reports MH-2375, MH-3134, MH-3072, MH-2630, MH-6138

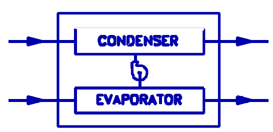
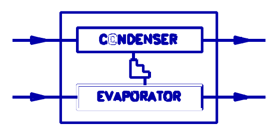
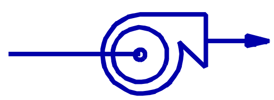
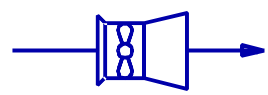
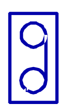
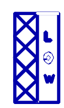
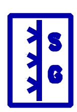
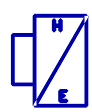
Heating Ventilation and Air Conditioning (HVAC) can be defined as control of the physical and chemical conditions of the atmosphere within a given structure. The factors that affect the conditions include the following:

- Temperature
- Humidity
- Air movement
- Air distribution
- Dust
- Bacteria
- Odors
- Toxic gases

It is incorrect to regard HVAC systems as simply the heating and cooling of air. HVAC is the means to change the air in the ways necessary to improve the comfort of those living or working in a structure. This may include warming or cooling the air, adding or subtracting moisture, filtering out contaminants such as dust, bacteria, or toxic gases, and maintaining proper distribution and movement of air. HVAC includes the following processes:

- Heating
- Cooling
- Humidifying
- Cleaning/Filtering
- Circulating

Figure 38 VENTILATION SYMBOLS

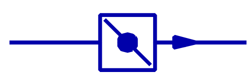
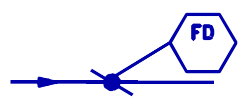
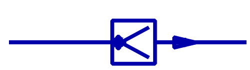
Refrigeration unit (centrifugal compressor)		Refrigeration unit (positive displacement compressor)	
Fan Centrifugal Flow		Fan Axial Flow	
Roll Type Filter		Filter	
Humidifiers		Coils (H-heating C-cooling)	

Compressors - are used in the refrigeration cycle. Compressors are used in refrigeration systems to raise the high temperature and pressure of the refrigerant gas. This is done so that the refrigerant will liquify in the condenser. The basic operation of a compressor is the same as a pump, the difference is that a compressor is designed to move a gas or vapor and pumps are designed to move a liquid.

Blowers - (or fans) are used to provide the motive force to move the air through a ventilation system. Fans are used to supply, circulate, distribute, and exhaust air. Blowers are designed to move large volumes of air at relatively low pressures. The blade of the fan uses the same principle of operation as a centrifugal pump. The blade acts as a propeller or impeller to move the gas. There are two main types of fans centrifugal or axial.

Dampers - are the valves of a ventilation system. The three major types of dampers are automatic, manual, and special operation dampers. Automatic dampers are positioned by actuators when a signal is sent. Manual dampers like manual valves are operated locally. Special operation dampers prevent airflow during certain unusual conditions such as during reverse flow due to tornado, heat during a fire, or for backflow conditions.

Figure 39 VENTILATION DAMPER SYMBOLS

Butterfly Damper		
Parallel Blade Damper		Used to isolate air flow. Blade tips have vinyl or silicone rubber sealing strings to provide positive seal. All blades move in same direction in unison.
Opposed Blade Damper		Used to throttle or regulate flow. Blades move in the opposite direction of adjacent blades. Flow controlled by varying the area between the blades.
Bubble Tight Damper		Serve as isolation dampers, 100% airtight seal provided when damper closed. Used for bypass dampers.
Fire Damper		Damper located in ventilation duct where the damper passes through a fire barrier. Held open by fusible or electro-thermal device. On high temperature spring forces damper closed. Contains blade lock to ensure damper stays closed until manual re-opened.
Tornado Damper		Located where ventilation duct enters building. Designed to close when outside air pressure drop significantly, like during a tornado. Prevents internal contamination from being drawn out through duct work to environment.

Backdraft Damper		Serves as a check valve in ventilation duct. Prevents air from flowing in the wrong direction. Requires no operator action, operates on differential pressure.

Heat exchangers - transfer heat from one material or medium to another. Used in several locations in the ventilation systems. In the refrigeration system there are two heat exchangers: the condenser and the evaporator. In the ventilation systems there are several including: chillers or cooling coils, heating coils preheat coils, booster coils, and reheat coils.

- Condenser - used to liquify or condense the refrigerant. High temperature, high pressure refrigerant gas enters and gives up the latent heat of vaporization to a heat sink. The refrigerant exits the heat exchanger as a slightly lower temperature slightly lower pressure liquid.
- Evaporator - used to cool a heat source by the refrigerant absorbing heat from the heat source. The refrigerant enters the evaporator as a low temperature low pressure liquid gas mixture. The refrigerant absorbs heat from the medium to be cooled and under goes a phase change by absorbing the latent heat of vaporization. The refrigerant leaves the evaporator as a higher temperature low pressure gas.
- Chiller - Cooling coils remove heat from the air. These coils may contain either chilled water or may be cooled by refrigerant inside the coils. Cool water or refrigerant flows through one side of the heat exchanger and warm air flows on the other side of the heat exchanger. The warm air gives up heat to the cool water. This is done for two purposes: one to provide cool air to increase the habitability of the working spaces and two to reduce the humidity in the air. Cool air holds less moisture than warm air. The air is cooled below the dewpoint by the chill water passing through the heat exchanger. When the air temperature reaches the dewpoint the moisture in the air condenses out on the cool piping of the chiller. Used during warm weather seasons.
- Heating coils add heat to the air with steam tubes, hot water tubes, natural gas, propane, oil, or electric heating elements. Designed to raise and maintain the air temperature in the desired temperature band.
- Preheat coils - used to heat the air as it enters the ventilation system from the outside. Used to prevent the cooling cools from freezing during cold weather. Used during cold weather seasons. Located upstream of the cooling coils.
- Booster coils - used to provide additional heat when the preheat coils can not supply enough heat to maintain the desired temperature of outside air. Also used to return the air temperature to the desired temperature after the air is cooled by the cooling coils for dehumidification. Located downstream of the cooling coils. Used all year long.

- Reheat coils - used to supply heating capability to supply duct or branches of the ventilation system. Normally installed in branch headers to control the temperature of a specific area.

Filters - remove particles from the air. This maintains the cleanliness of the ventilation system. The advantages of clean air in a ventilation system are reduced fan wear and the ability to maintain the heat transfer efficiency of heating/cooling tubes by preventing buildup on the surfaces of the heat transfer surfaces. Maybe installed in suction headers to prevent outside dust and contaminants from entering the facility building. Or may be installed in exhaust ventilation to prevent internal contaminants and radioactive material from being exhausted to the environment. Come in many styles, materials, and ratings.

Typically the filters are installed to remove particle of decreasing size. The first filter is designed to remove the large pieces. The next filter removes slightly smaller particles. The final filter removes the smallest particles. The pre-filter removes larger particles of dust and lint which extends the operating cycle of the downstream filters. The HEPA filter removes high percentage of air particles down to the sub-micron size. An adsorber uses a sorbent to remove molecules from the air. Common adsorber filters include activated charcoal and fluorocarbons.

Hoods - One of the most common engineering controls used for airborne contaminants is the Chemical Fume Hood. The fume hood is basically an enclosed workspace with an open front to allow access to the work area. The fume hood is used for contaminant levels of about ten (10) times the allowable limit. The fume hood draws air into the hood allowing personnel to work with materials in the hood and not release the contaminants into the work space. Air flow into the hood must be sufficient to ensure no contaminants will escape the hood yet not so great as to cause turbulence in the hood and create a backflow problem causing contaminants to "spill" out of the hood. Hoods are usually connected to the ventilation system with a HEPA filter in line to prevent contaminants from entering the ventilation system and being vented to the atmosphere.

Glove Box - A glove box is similar to the hood except it is fully enclosed with access provided by gloves installed in a window area for visual examination. A glove box is used when the contamination levels being worked with exceeds 10 times the allowable limits for a contaminant. Generally the air flow through a glove box is minimal; just enough to create a small negative pressure of about 0.5" of water in the glove box.

Hot Cells - refers to areas used for the processing of highly radioactive materials where radiation exposure is a concern. These areas may be in the form of a glove box, hood, or room. They can also be used to ensure containment of the contamination. The systems are typically under a negative pressure to ensure positive air flow from outside the hot cell to within the cell and out the ventilation system. The ventilation system normally contains radiation monitoring equipment to ensure no contamination enters the system past the in line HEPA filter banks. Also included are differential pressure detectors to indicate when the filters are becoming plugged. HEPA filter may be changed out based upon the differential pressure of radiation levels of the filters.

Pressure Sensors - pressure sensors are used to detect system, room, or differential pressure and provide input into various components of a ventilation system. Pressure sensors may be used to determine loading of a filter or absolute pressure of room. Pressure sensors can be divided into three categories:

- standards, such as a liquid column manometer
- mechanical, such as a bourdon tube;
- electro-mechanical transducer which combines a mechanical sensor such as a bourdon tube, capsule, or diaphragm with electronic means to detect the distortion of the sensor to provide a readout.

Scrubbers - Scrubbers are normally placed in closed ventilation systems or are stand alone units in areas where fresh air exchange is impossible or limited. The scrubbers are use to remove contaminants from the air. The scrubber process the air such that the contaminants such as Carbon dioxide are removed, condensed, and stored for removal and disposal while the purified air is discharged back into the system.

Differential pressure across filters - Pressure is monitored across filters to determine filter loading and flow characteristics. If differential pressure is not monitored there is the possibly of rupturing the filter thus allowing contaminants to flow into the remainder of the system. If the filter differential pressure is not monitored the rupture will go unnoticed. Also differential pressure will indicate if the filter is clogged and proper flow is not occurring, thereby not allowing the system to perform the job for which it was intended.

Differential pressure across components - Like filters the differential pressure across components is very important. If the flow across the component is not sufficient (indicated by a high differential pressure) the component may over heat. If there is no differential pressure there may be a leak in the component allowing outside air to enter create an inefficient cooling of the component.

An HVAC system maintains desired environmental conditions within a building or space. In almost every application there is a myriad of options available to satisfy the basic goal. HVAC systems are categorized by how they control environment in the conditioned area. They are also segregated to accomplish specific purposes by special equipment arrangements. Due to the variations in types of HVAC systems, It is suggested that you consult the listed references which describes the many types of systems.

If HVAC systems are operating properly they are eliminating hazards, not causing them. However, in the event of a malfunction problems may arise. The problems or hazards generated would be specific to the equipment, components rooms, or facilities being serviced by the HVAC system in question. Therefore, the potential problems that arise could arise are numerous and varied. A failed HVAC system may allow the overheating of rooms causing a unfavorable condition for equipment operation or personnel entry. If a HEPA filter in line ruptures or is loaded excessively, breakthrough occurs. Breakthrough is the point where the particles designed to be trapped penetrate or flow through the filter. Breakthrough could allow contamination to be carried to other parts of the building exposing personnel, contaminating areas, or release to the environment, placing the public at risk.

Poorly placed HVAC systems may cause outside contaminants to be brought into a building, such as engine exhaust from nearby generators or cars. If a ventilation system fails and the confinement system is designed to ensure air flow from areas of no contamination to high contamination, the air flow could reverse causing the spread of contamination to unwanted areas or personnel.

In order to fully understand the potential problems it is necessary to understand all of the purposes and designs of HVAC systems for the specific facility at which you are located or evaluating. Once the facility of concern is identified the following references will assist in identifying the purpose and operation of the equipment and any potential problems that may arise for its failure or malfunction.

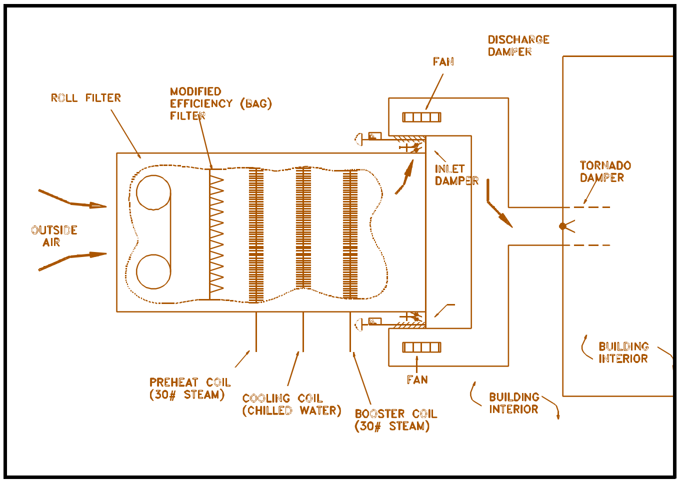


Figure 40 Air Supply Unit

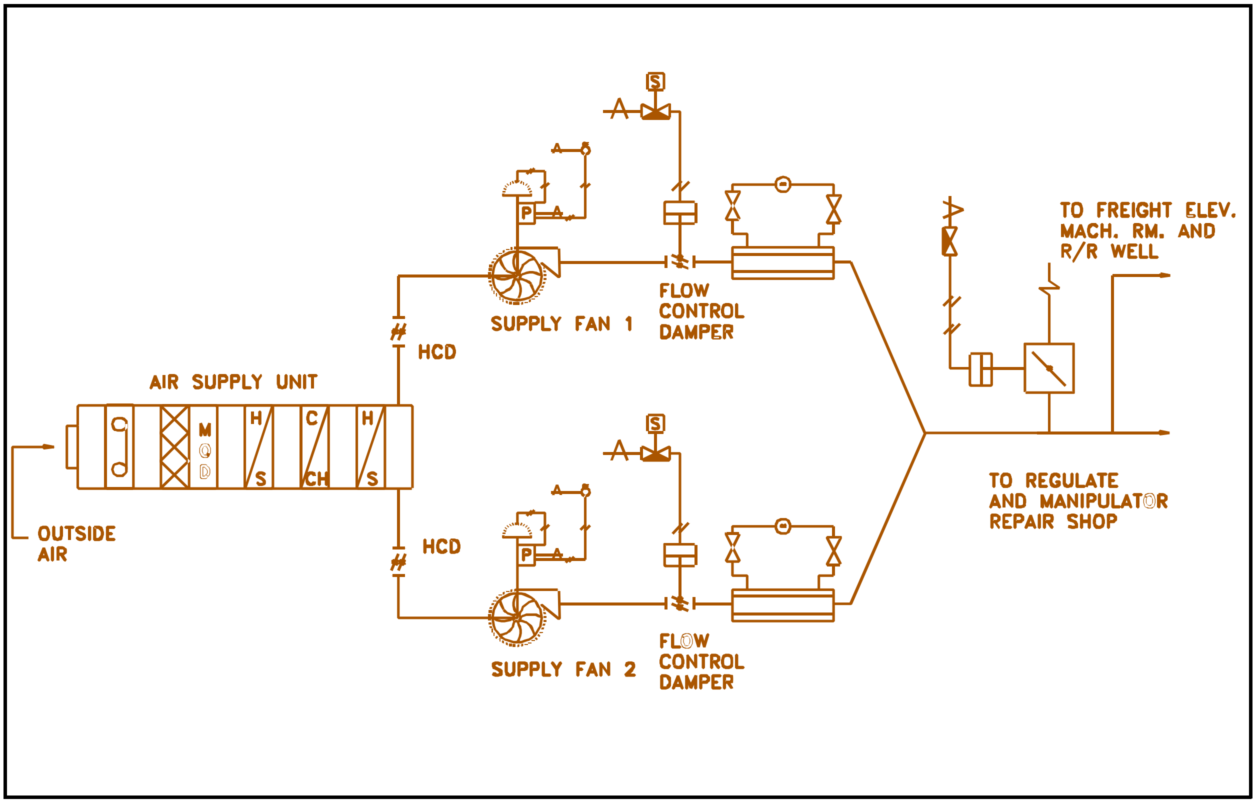


Figure 41 Air Handling Unit

Air Handling Unit provides a housing for the heating and cooling coils, various filters, dampers, and a blower or fan to move the air through the system. It also provides a mixing area for return air and supply air from the outside.

Humidifiers add water/moisture to the air. Sufficient humidity reduces static electricity that may damage electronics, aid in comfort, and reduce drying and loosening of wood furniture. Low humidity occurs when the outside air temperature is low. As air is heated the humidity will drop unless additional moisture is added.

Supply air is moved by supply fans or an air supply unit. It supplies 100% outside air into an area for supply to the air handling unit for distribution.

Return air is moved by the action of fans. The fans remove air from ventilated areas and return it to the air handling unit for mixing. Return air not mixed with the supply air is returned outside as exhaust air.

Exhaust air may be moved by an exhaust air unit and exhaust fans to assist the air handling unit control negative pressure and force exhaust air through filters or stacks. Exhaust air does not mix with supply air.

Refrigeration - Heat transfer from a system below ambient temperature using a mechanical system. Two system types are the vapor compression system and the waste vapor absorption system.

Heat - The transfer of internal molecular energy.

Specific heat - The amount of energy required to raise the temperature of one pound of that substance one degree Fahrenheit.

Subcooled liquid - A condition of temperature and pressure when a liquid is at some temperature below the saturation temperature.

Superheated gas - A condition of temperature and pressure when a gas is at some temperature below the saturation temperature.

Saturation - A condition of temperature and pressure when a liquid or gas changes state.

British Thermal Unit (BTU) - A unit of energy needed to raise the temperature of 1 lbm of water 1 Fahrenheit degree.

Latent heat of vaporization - the latent heat (no temperature change only phase change) required to change a liquid into a gas. The temperature remains constant all the energy added goes to breaking the bonds that hold the material in a liquid state. The latent heat of vaporization occurs at the temperature also referred to as the boiling point of a material.

Vaporization point - the point (temperature and pressure) where if enough energy (latent) is added a liquid changes into a gas. It is also the point as which a gas condenses into a liquid if enough energy is removed. As the heat is added to a liquid the temperature remains constant until all of the liquid undergoes a phases change to gas.

Latent heat of fusion - the amount of latent heat (no temperature change only phase change) required to change a solid into a liquid. The temperature remains constant all the energy added goes to breaking the bonds that hold the material in a solid state. The latent heat of fusion occurs at the temperature also referred to as the freezing point or melting point of a material.

Refrigerant - is the working fluid in a refrigeration system. It absorbs heat by vaporizing at a low temperature and pressure and then transfer heat by condensing at a high temperature and pressure. A good refrigerant changes phase from a liquid to a gas at a low temperature.

Refrigerants are the vital working fluids used for cooling in refrigeration systems. These chemicals absorb heat from a place it is not wanted and disposes of the heat elsewhere. Heat is removed from the system by the evaporation of the liquid refrigerant and is disposed of by condensing the refrigerant vapor. Some of the refrigerants used in the air conditioning systems include:

Chlorotrifluoromethane, Refrigerant 13
Trichlorofluormethane, Refrigerant 11
Dichlorodifluoromethane, Refrigerant 12
Tetrafluoromethane, Refrigerant 14
Ammonia, Refrigerant 717

A refrigerant should possess properties that permit efficient and safe operation. Those properties include the following:

- Low boiling point
- Nontoxic and nonirritating
- Nonexplosive
- Nonflammable
- Mixes well with oil
- Operation on a positive pressure
- High latent heat value
- Not affected by moisture

Formerly, two of the more commonly used refrigerants were Freon 12 and Freon 22. These are clear, almost colorless liquids at temperatures below their boiling point. Efforts are taking place to replace these refrigerants with environmentally friendly refrigerants as the technology is developed and cost decreases.

Although typically not in use in DOE facilities operators should be aware some organic refrigerants like ammonia, propane, and propylene are explosive, flammable, and/or highly toxic.

Hazards of Refrigerants

Most refrigerants have some exposure hazards associated with them. The concentration and length of time exposed to the refrigerants is important and varies with each type of refrigerant. Some refrigerants are flammable and explosive limits should be considered.

1) Refrigerants can cause freezing of skin or material it comes in contact with. This especially true of refrigerants being released at pressure. Always wear protective clothing, gloves, and eye protection.
2) Freon is an asphyxiant. In high concentrations the freon gas displaces the oxygen and can cause breathing difficulty. Freon is more dense than air so it settle to low points. When working on freon system ensure adequate ventilation is used.
3) When exposed to open flame or high temperatures (>600°F) chlorofluorocarbon refrigerants (freon) under goes a chemical reaction forming highly toxic phosgene gas. (Phosgene was used in WWI for chemical warfare.) No smoking, cutting or burning should take place in areas exposed to freon gas.
4) Recent scientific data has associated freon with the depletion of the ozone layer. Freon (and other gases) discharged to the atmosphere gradually migrate to the upper atmosphere. The chlorine atoms in the freon (chlorofluorocarbon) react act as a catalyst in the ultraviolet rays from the sun to breakdown the oxygen bonds in the ozone. Care and precautions are require to prevent accidental release of freon to the environment.
5) In addition to the chemical hazards associated with freon consider also:
   a) Freon may be absorbed in the lubricating oil of the compressor. Handle the oil with the same precautions of handling freon.
   b) Some refrigerants are stored in cylinders at high pressures. The cylinders should always be secure. Ensure all precaution for handling pressurized cylinders are followed.
   c) Exercise extreme caution around rotating equipment. The moving parts of the compressor may entangle jewelry or lose clothing.

Refrigerant leak detection

The detection of leaks in refrigeration equipment is a major problem for manufacturers and service engineers. Refrigerant leak detection is important to ensure that the refrigerant being used does not escape to the environment. This is important from a cost control stand point and an environmental control standpoint.

The detection of ammonia is done by burning a sulphur candle in the vicinity of the suspected leak or by bringing a solution of hydrochloric acid near the object.

Sulfur dioxide can be detected by the appearance of white smoke when aqueous ammonia is brought near the leak. Other methods of leak detection include:

Bubble Method
Electronic Detector
Halide Torch

Two main methods are used to detect leaks, one low tech and one high tech. The low tech method is called the soap bubble method. The system to be tested is pressurized. The system pressure is monitored. If the pressure decreases the system has a leak. All piping, fitting, and connections are "painted" with a liquid solution that contains soap. Where the leak occurs the soap film will create bubbles. The high tech method uses a freon detector or "snoop". The detector is sensitive to low levels of the refrigerant. Again the system is pressurized and monitored for a pressure leak. The refrigerant detector sensor is traced over the piping, fittings, and connectors. When the sensor detects refrigerant the detector will alarm.
Compressors are used in refrigeration systems to raise the high temperature and pressure of the refrigerant gas. This is done so that the refrigerant will liquify in the condenser. The basic operation of a compressor is the same as a pump, the difference is that a compressor is designed to move a gas or vapor and pumps are designed to move a liquid.

Types of refrigeration compressors

A centrifugal compressor. The spinning motion of the impeller is used to increase the velocity of the refrigerant gas. In the volute of the compressor the kinetic energy (velocity) of the refrigerant is converted into pressure by the increasing area of the volute. The high temperature, low pressure gas exiting the evaporator is drawn into the suction of the compressor. The centrifugal compressor raising the temperature and pressure of the refrigerant. The high temperature, high pressure gas is discharged to the condenser. In larger centrifugal compressor, pre-rotation inlet vanes direct the gas into the eye of the impeller to increase the efficiency of the compressor. The pre-rotation vanes are used to regulate how much refrigerant enters the compressor. During high heat loads the pre-rotation vanes are flow open. The other component associated with a centrifugal compressor is a "hot gas bypass valve". This valve is used during low load conditions when not enough refrigerant is flowing through the system. The bypass valve direct refrigerant directly from the compressor discharge back to the compressor suction. This allow sufficient flow of refrigerant through the compressor. Advantages of centrifugal compressors are they weight less, are more compact, and have less vibration than a reciprocating compressor of the same size. They also have fewer moving parts to wear.

A reciprocating compressor. The rotary motion of the crankshaft is converted to linear motion of the pistons. The high temperature, low pressure gas exiting the evaporator is drawn into the suction of the compressor. The piston compresses the gas, rasing the temperature and pressure. The high temperature, high pressure gas is discharged to the condenser. This type of compressor is a positive displacement pump. A constant volume of gas is compressed on each stroke.

Metering devices (orifice and thermal expansion valve)

Two main methods of controlling the conversion of the moderate high temperature and High pressure refrigerant into a low temperature and low pressure liquid gas mixture. They are the expansion orifice and the thermostatic expansion valve. Both serve the same purpose but are accomplished slightly differently. Both devices are located between the condenser and the evaporator. In the condenser the high temperature and high pressure gas undergoes a phase change as the latent heat of vaporization is removed. This creates a slightly lower temperature, slightly lower pressure liquid. In the evaporator the refrigerant is heated by the fluid to be cooled. The refrigerant absorbs the latent heat of vaporization from the medium to be cooled. The refrigerant leaving the evaporator is a moderately high temperature low pressure gas.

The expansion orifice is a non-adjustable orifice that allows a pressure drop in the refrigeration system. The orifice is located downstream of the condenser. Upstream of the orifice the refrigerant is a moderately high temperature and high pressure liquid. As the refrigerant flows through the small opening in the orifice plate, a pressure drop occurs. The pressure of the system drops below the saturation pressure of the liquid refrigerant. Below the saturation pressure, a small percentage of the refrigerant flashes to a vapor. The vapor is referred to as "flash gas". The flash gas causes the temperature of the remaining liquid to drop.

The second method is the thermostatic expansion valve. The thermostatic expansion valve also causes a pressure drop. The thermostatic expansion valve is downstream of the condenser. The benefit of the thermostatic expansion valve is that it also controls the flow of refrigerant through the system. The position of the thermostatic valve is controlled by the temperature of the refrigerant leaving the evaporator. A sealed sensing bulb is attached to the refrigerant line. As the temperature of the refrigerant leaving the evaporator decreases the pressure of the refrigerant in the sensing bulb also decreases. The decrease in pressure of the sensing bulb is felt on a diaphragm that repositions the thermostatic expansion valve stem and disc. As the pressure decreases spring pressure overcomes the pressure above the diaphragm and the valve closes. If the heat load on the evaporator increases, the refrigerant flowing through the evaporator is not sufficient to cool the load. This causes the temperature of the refrigerant to increase. The sensing bulb heats up and the pressure in the sensing bulb increases. The increased pressure is felt above the diaphragm overcoming the spring pressure and opening the valve. More freon is admitted to the evaporator. More freon means the system can absorb more heat. If the heat load remains constant, the increase in freon flow can carry off more heat energy and gradually the temperature is reduced.

Air and non-condensible gases - In the working fluid side of a refrigeration unit the system is filled with refrigerant. After the refrigerant exits the compressor as a high temperature and high pressure gas it enters the condenser. A cooling medium on the other side of the heat exchanger removes the latent heat of vaporization. The refrigerant is condensed into a slightly lower temperature slightly lower pressure liquid. If air or other non-condensible gases leak into the refrigerant in portions of the system when the refrigerant is at a low pressure, the non-condensible gases will be transported with the refrigerant to the condenser. Unlike the refrigerant, the non-condensible gases do not condense in the condenser. The non-condensible gases build up in the upper regions condenser preventing the condenser from condensing the refrigerant. If the non-condensible gases continue to collect they create a higher pressure in the condenser that the compressor must pump against. This decreases the efficiency of the compressor, making the compressor work harder to do the same amount of cooling. The non-condensible gases are removed by a purge unit.

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **K&S 1.16-Q.1.a. and K&S 1.17-R.1.a.** refer to:

- American Society of Heating, Refrigeration and Air-conditioning Engineers, (1990). ASHRAE HANDBOOK Refrigeration Systems and Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
- American Society of Heating, Refrigeration and Air-conditioning Engineers, (1991). ASHRAE HANDBOOK HVAC Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
- American Society of Heating, Refrigeration and Air-conditioning Engineers, (1992). ASHRAE HANDBOOK HVAC Systems and Equipment. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
- Gollnick, Daniel A., (1994). Basic Radiation Protection Technology Third Edition. Altadena, CA: Pacific Radiation Corporation.
- American Society of Heating, Refrigeration and Air-conditioning Engineers, (1993). ASHRAE HANDBOOK Fundamentals. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Refrigeration.
- Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 7, Lesson 6, Ventilation Fundamentals.
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Refrigeration.
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Ventilation.
- Bureau of Naval Personnel (revised 1969). Refrigeration and Air Conditioning (NAVPERS 16163-A). Stock Ordering No. 0502-LP-080-8150.
- Brumbaugh, James E. (1983). Heating, Ventilating and Air Conditioning Library Volume 3. Indianapolis, IN: Bobbs Merrill Company, Inc. ISBN 0-672-23383-5. Chapter Air Conditioning Principles.

b. For Supporting Knowledge and Skills **K&S 1.16-Q.1.b. and K&S 1.17-R.1.b.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Ventilation.
   - Bureau of Naval Personnel (revised 1969). <u>Refrigeration and Air Conditioning (NAVPERS 16163-A)</u>. Stock Ordering No. 0502-LP-080-8150.

c. For Supporting Knowledge and Skills **K&S 1.16-Q.1.c. and K&S 1.17-R.1.d.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Ventilation.

d. For Supporting Knowledge and Skills **K&S 1.16-Q.1.d.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Ventilation.

e. For Supporting Knowledge and Skills **K&S 1.16-Q.1.e.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Refrigeration.
   - Bureau of Naval Personnel (revised 1969). <u>Refrigeration and Air Conditioning (NAVPERS 16163-A)</u>. Stock Ordering No. 0502-LP-080-8150.
   - Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Refrigeration.
   - American Society of Heating, Refrigeration and Air-conditioning Engineers, (1992). <u>ASHRAE HANDBOOK HVAC Systems and Equipment</u>. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
   - American Society of Heating, Refrigeration and Air-conditioning Engineers, (1991). <u>ASHRAE HANDBOOK HVAC Applications</u>. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
   - American Society of Heating, Refrigeration and Air-conditioning Engineers, (1990). <u>ASHRAE HANDBOOK Refrigeration Systems and Applications</u>. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
   - American Society of Heating, Refrigeration and Air-conditioning Engineers, (1993). <u>ASHRAE HANDBOOK Fundamentals</u>. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.

f. For Supporting Knowledge and Skills **K&S 1.16-Q.1.f.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Ventilation.
- Bureau of Naval Personnel (revised 1969). Refrigeration and Air Conditioning (NAVPERS 16163-A). Stock Ordering No. 0502-LP-080-8150.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Refrigeration.
- American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc, (1992). ASHRAE Handbook and Product Directory, 1992 HVAC Systems and Equipment. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers. ISBN 0-910110-87-5.

g. For Supporting Knowledge and Skills **K&S 1.16-Q.1.g. and K&S 1.17-R.1.g.** refer to:
- Brumbaugh, James E. (1983). Heating, Ventilating and Air Conditioning Library Volume 3. Indianapolis, IN: Bobbs Merrill Company, Inc. ISBN 0-672-23383-5. Chapter Air Conditioning Principles.
- Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 7, Lesson 5, Air Conditioning and Refrigeration.
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Refrigeration.
- Bureau of Naval Personnel (revised 1969). Refrigeration and Air Conditioning (NAVPERS 16163-A). Stock Ordering No. 0502-LP-080-8150.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Refrigeration.

h. For Supporting Knowledge and Skills **K&S 1.16-Q.1.h. and K&S 1.17-R.1.j.** refer to:
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Refrigeration.
- Westinghouse Savannah River Company High Level Waste Operator Training Heat Transfer and Fluid Flow Study Guide (NWMOG009.H0102) Chapter Heating and Cooling Processes in Fluids.
- Bureau of Naval Personnel (revised 1969). Refrigeration and Air Conditioning (NAVPERS 16163-A). Stock Ordering No. 0502-LP-080-8150.

i. For Supporting Knowledge and Skills **K&S 1.16-Q.1.i.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Refrigeration.
   - Brumbaugh, James E. (1983). <u>Heating, Ventilating and Air Conditioning Library Volume 3</u>. Indianapolis, IN: Bobbs Merrill Company, Inc. ISBN 0-672-23383-5. Chapter Refrigerants.
   - Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 7, Lesson 5, Air Conditioning and Refrigeration.
   - American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. (1980). <u>ASHRAE Handbook and Product Directory, 1977 Fundamentals</u>. New York, NY: American Society of Heating, Refrigeration and Air-Conditioning Engineers. Chapter 15, Refrigerants.
   - American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 34-67.
   - American National Standards Institute (ANSI) B79.1.
   - Bureau of Naval Personnel (revised 1969). <u>Refrigeration and Air Conditioning (NAVPERS 16163-A)</u>. Stock Ordering No. 0502-LP-080-8150.
   - Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Refrigeration.

j. For Supporting Knowledge and Skills **K&S 1.16-Q.1.j. and K&S 1.17-R.1.l.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Refrigeration.
   - Brumbaugh, James E. (1983). <u>Heating, Ventilating and Air Conditioning Library Volume 3</u>. Indianapolis, IN: Bobbs Merrill Company, Inc. ISBN 0-672-23383-5. Chapter Refrigerants.
   - Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 7, Lesson 5, Air Conditioning and Refrigeration.
   - American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc, 1980. <u>ASHRAE Handbook and Product Directory, 1977 Fundamentals</u>. New York, NY: American Society of Heating, Refrigeration and Air-Conditioning Engineers. Chapter 15, Refrigerants
   - Underwriters Laboratories Reports MH-2375, MH-3134, MH-3072, MH-2630, MH-6138
   - Naval Training Command (revised 1972). <u>Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D)</u>. Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Refrigeration.

k. For Supporting Knowledge and Skills **K&S 1.17-R.1.c.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Ventilation.
   - Bureau of Naval Personnel (revised 1969). Refrigeration and Air Conditioning (NAVPERS 16163-A). Stock Ordering No. 0502-LP-080-8150.

l. For Supporting Knowledge and Skills **K&S 1.17-R.1.e.** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Ventilation.

m. For Supporting Knowledge and Skills **K&S 1.17-R.1.f.** refer to:
   - American Society of Heating, Refrigeration and Air-conditioning Engineers, (1992). ASHRAE HANDBOOK HVAC Systems and Equipment. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
   - American Society of Heating, Refrigeration and Air-conditioning Engineers, (1991). ASHRAE HANDBOOK HVAC Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
   - American Society of Heating, Refrigeration and Air-conditioning Engineers, (1990). ASHRAE HANDBOOK Refrigeration Systems and Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
   - American Society of Heating, Refrigeration and Air-conditioning Engineers, (1993). ASHRAE HANDBOOK Fundamentals. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.

n. For Supporting Knowledge and Skills **K&S 1.17-R.1.h.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Refrigeration.
   - Bureau of Naval Personnel (revised 1969). Refrigeration and Air Conditioning (NAVPERS 16163-A). Stock Ordering No. 0502-LP-080-8150.

o. For Supporting Knowledge and Skills **K&S 1.17-R.1.i.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Refrigeration.
   - Bureau of Naval Personnel (revised 1969). Refrigeration and Air Conditioning (NAVPERS 16163-A). Stock Ordering No. 0502-LP-080-8150.
   - Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter Refrigeration.

p. For Supporting Knowledge and Skills **K&S 1.17-R.1.k.** refer to:

- American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. (1980). ASHRAE Handbook and Product Directory, 1977 Fundamentals. New York, NY: American Society of Heating, Refrigeration and Air-Conditioning Engineers. Chapter 15, Refrigerants.

4. Practice Exercise

a. List four (4) parameters control by the Heating, Ventilation, and Air Conditioning (HVAC) and the means of controlling. (K&S 1.16-Q.1.a.) (K&S 1.17-R.1.a.)

Parameter	Means of Controlling

b. Describe the purpose and operation of the "Cascade Pressure Control System". (K&S 1.16-Q.1.c.) (K&S 1.17-R.1.d.)

c. Why is it necessary to control the Differential pressure across filters? (K&S 1.16-Q.1.d.)

d. Draw and label a simplified diagram of the refrigeration cycle showing the four (4) major components. (K&S 1.16-Q.1.g.) (K&S 1.17-R.1.g.)

e. State the name and purpose of the four (4) major components in the refrigeration cycle. (K&S 1.16-Q.1.g.) (K&S 1.17-R.1.g.)

1.

2.

3.

4.

f. Define the term Latent heat of vaporization as they apply to air conditioning and refrigeration systems: (K&S 1.16-Q.1.h.) (K&S 1.17-R.1.j.)

g. List four (4) desirable characteristics of a refrigerant used in air conditioning systems. (K&S 1.16-Q.1.i.)

1.

2.

3.

4.

h. List four (4) hazards associated with the refrigerant FREON. (K&S 1.16-Q.1.j.) (K&S 1.17-R.1.l.)

1)

2)

3)

4)

i. Compare and contrast the principles of operation for centrifugal and reciprocating refrigeration compressors. (K&S 1.17-R.1.h.)

j. Using a cutaway drawing of a typical thermal expansion valve and sensing bulb, explain its principle of operation. (K&S 1.17-R.1.i.)

k. Why is detection of refrigerant leaks important? (K&S 1.17-R.1.k.)

5. Practice Exercise Answers

a. List four (4) parameters control by the Heating, Ventilation, and Air Conditioning (HVAC) and the means of controlling. (K&S 1.16-Q.1.a.) (K&S 1.17-R.1.a.)

Parameter	Means of Controlling
Temperature	Heating coils Cooling Coils
Humidity	Cooling coils Humidifiers
Air movement	Fans Dampers
Air distribution	Fans Dampers
Dust	Filtration Dilution
Bacteria	Filtration Dilution
Odors	Filtration Dilution
Toxic gases	Filtration Dilution

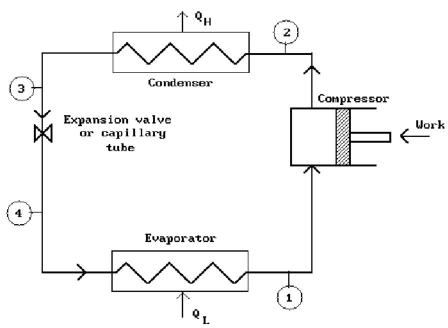
b. Identify and discuss when maintaining a negative pressure in an heating, ventilation and air conditioning system is desirable. (K&S 1.16-Q.1.c.) (K&S 1.17-R.1.d.)

A common system for controlling the cleanliness of a ventilation system is called the "Cascade Pressure Control System". The system is set up to maintain the area with the highest levels of contamination at the low pressures or negative pressures when compared to the surrounding areas. This method is used to ensure that air leaks or flows into the most contaminated area.

c. Why is it necessary to control the Differential pressure across filters? (K&S 1.16-Q.1.d.)

If the differential pressure is not correct the filter may not work as designed. Too high of a differential pressure maybe an indication the filter is clogged. This may result in insufficient air flow to supplied loads.

d. Draw and label a simplified diagram of the refrigeration cycle showing the four (4) major components. (K&S 1.16-Q.1.g.) (K&S 1.17-R.1.g.)



Ideal Vapor - Compression Refrigeration Cycle

e. State the name and purpose of the four (4) major components in the refrigeration cycle. (K&S 1.16-Q.1.g.) (K&S 1.17-R.1.g.)

   Compressor - provide the force to the refrigerant causing movement of the refrigerant throughout the system cycle. Compressors are used to receive and compress low-pressure refrigerant vapor into a smaller volume at higher pressure.

   Condenser - is a heat exchanger where the refrigerant heat rejection occurs in the system. During operation, hot discharge gas from the compressor enters the condenser coil at the top and as it is condensed, drains out of the condenser to a receiver located at the lower level. The condenser coil is located along with the compressor and controlling devices in the condensing unit.

   Thermal expansion valve/Metering device/orifice - regulates the pressure and flow of refrigerant throw the system. Creates a pressure drop so that the high pressure high temperature gaseous refrigerant will flash to a low pressure low temperature liquid-gaseous mixture.

   Evaporators - is the heat exchanger where the refrigerant absorbs heat from the medium to be cooled. During operation, low temperature low pressure liquid-gaseous mixture absorbs heat creating a low pressure slightly higher temperature gas.

f. Define the term Latent heat of vaporization as they apply to air conditioning and refrigeration systems: (K&S 1.16-Q.1.h.) (K&S 1.17-R.1.j.)

   The quantity of heat that becomes concealed in a body while producing the change of state of a liquid to a gas. This transfer of heat however does not change the temperature.

g. List four (4) desirable characteristics of a refrigerant used in air conditioning systems. (K&S 1.16-Q.1.i.)

   - Low boiling point
   - Nontoxic and nonirritating
   - Nonexplosive
   - Nonflammable
   - Mixes well with oil
   - Operation on a positive pressure
   - High latent heat value
   - Not affected by moisture

h. List four (4) hazards associated with the refrigerant FREON. (K&S 1.16-Q.1.j.) (K&S 1.17-R.1.l.)

1) Refrigerants can cause freezing of skin or material it comes in contact with. This especially true of refrigerants being released at pressure. Always wear protective clothing, gloves, and eye protection.
2) Freon is an asphyxiant. In high concentrations the freon gas displaces the oxygen and can cause breathing difficulty. Freon is more dense than air so it settle to low points. When working on freon system ensure adequate ventilation is used.
3) When exposed to open flame or high temperatures (>600°F) chlorofluorocarbon refrigerants (freon) under goes a chemical reaction forming highly toxic phosgene gas. (Phosgene was used in WWI for chemical warfare.) No smoking, cutting or burning should take place in areas exposed to freon gas.
4) Recent scientific data has associated freon with the depletion of the ozone layer. Freon (and other gases) discharged to the atmosphere gradually migrate to the upper atmosphere. The chlorine atoms in the freon (chlorofluorocarbon) react act as a catalyst in the ultraviolet rays from the sun to breakdown the oxygen bonds in the ozone. Care and precautions are require to prevent accidental release of freon to the environment.

i. Compare and contrast the principles of operation for centrifugal and reciprocating refrigeration compressors. (K&S 1.17-R.1.h.)

A centrifugal compressor. The spinning motion of the impeller is used to increase the velocity of the refrigerant gas. In the volute of the compressor the kinetic energy (velocity) of the refrigerant is converted into pressure by the increasing area of the volute. The high temperature, low pressure gas exiting the evaporator is drawn into the suction of the compressor. The centrifugal compressor raising the temperature and pressure of the refrigerant. The high temperature, high pressure gas is discharged to the condenser. In larger centrifugal compressor, pre-rotation inlet vanes direct the gas into the eye of the impeller to increase the efficiency of the compressor. The pre-rotation vanes are used to regulate how much refrigerant enters the compressor. During high heat loads the pre-rotation vanes are flow open. The other component associated with a centrifugal compressor is a "hot gas bypass valve". This valve is used during low load conditions when not enough refrigerant is flowing through the system. The bypass valve direct refrigerant directly from the compressor discharge back to the compressor suction. This allow sufficient flow of refrigerant through the compressor. Advantages of centrifugal compressors are they weight less, are more compact, and have less vibration than a reciprocating compressor of the same size. They also have fewer moving parts to wear.

A reciprocating compressor. The rotary motion of the crankshaft is converted to linear motion of the pistons. The high temperature, low pressure gas exiting the evaporator is drawn into the suction of the compressor. The piston compresses the gas, rasing the temperature and pressure. The high temperature, high pressure gas is discharged to the condenser. This type of compressor is a positive displacement pump. A constant volume of gas is compressed on each stroke.

j. Using a cutaway drawing of a typical thermal expansion valve and sensing bulb, explain its principle of operation. (K&S 1.17-R.1.i.)

The thermostatic expansion valve is downstream of the condenser. The position of the thermostatic valve is controlled by the temperature of the refrigerant leaving the evaporator. A sealed sensing bulb is attached to the refrigerant line. As the temperature of the refrigerant leaving the evaporator decreases the pressure of the refrigerant in the sensing bulb also decreases. The decrease in pressure of the sensing bulb is felt on a diaphragm that repositions the thermostatic expansion valve stem and disc. As the pressure decreases spring pressure overcomes the pressure above the diaphragm and the valve closes. If the heat load on the evaporator increases, the refrigerant flowing through the evaporator is not sufficient to cool the load. This causes the temperature of the refrigerant to increase. The sensing bulb heats up and the pressure in the sensing bulb increases. The increased pressure is felt above the diaphragm overcoming the spring pressure and opening the valve. More freon is admitted to the evaporator. More freon means the system can absorb more heat. If the heat load remains constant, the increase in freon flow can carry off more heat energy and gradually the temperature is reduced.

k. Why is detection of refrigerant leaks important? (K&S 1.17-R.1.k.)

Refrigerant leak detection is important to ensure that the refrigerant being used does not escape to the environment or work spaces. This is important from a cost control stand point and an environmental control standpoint.

This page is intentionally blank.

S. **Competency 1.18**

A Facility Representative (FAC# 1.1) shall demonstrate a familiarity level knowledge of principles of steam system operation including theory, components, startup, normal and off-normal operation, and shutdown.

1. Supporting Knowledge and Skills

   a. Explain the application of the following concepts to steam systems:

   - Enthalpy
   - Saturation
   - Superheat
   - Steam quality
   - Moisture content
   - Condensation
   - Sensible heat
   - Carryover
   - Thermal expansion
   - Thermal contraction

   b. Explain the of use Steam Tables and the Mollier Diagram and demonstrate their use.

   c. Using the Steam Tables and/or Mollier Diagram determine the changes to steam temperature and condition (enthalpy, moisture content, saturation, superheat, pressure) for the following steam processes:

   - Throttling
   - Pressure reduction
   - Steam leak
   - Temperature changes
   - Condensation
   - Venturi flow
   - Evaporation
   - Boiling

   d. Describe condensation-induced water hammer and its potential impact on steam systems.

e. Explain the function/application of the following steam system components and describe how the components contribute to steam system operation:

- Isolation Valves
- Isolation Valve Bypass Valves
- Vent Valves
- Drain Valves
- Safety/Relief Valves
- Flow Control Valves
- Steam Trap Bypass Valves
- Expansion Joints
- Pressure Control Valves
- Moisture Separators
- Pipe Hangers/Supports
- Mist Eliminators
- Evaporators
- Condensers
- Steam Generators/Reboilers
- Turbines
- Drip Legs
- Flash Tanks
- Steam Traps (mechanical, impulse, thermostatic)

    DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Steam Traps, page 35-39.

f. Describe the following steam system evolutions and associated precautions:

- Pressurization and warm-up of a cold steam system
- Initiation of steam flow in a stagnant, but pressurized steam system
- Isolation of a portion of a steam system
- Pressurization and warm-up of an isolated portion of a steam system
- Isolation and de-pressurization of an in-service steam system

g. Describe the expected operator response to, and where possible, how to prevent the following steam system abnormal conditions. Include a discussion of associated hazards:

- Water hammer during pressurization/warm-up of a cold steam system
- Water hammer during initiation of flow in an in-service steam system
- Seat leakage of an isolation valve
- Steam leakage to atmosphere
- Steam header rupture

T. Competency 1.19

Mechanical systems (FAC# 1.6) personnel shall demonstrate working level knowledge of general piping systems and piping system maintenance.

1. Supporting Knowledge and Skills

a. Discuss the purpose and operation of steam traps.
DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2, Module 5, Miscellaneous Mechanical Components, Chapter Steam Traps, page 35-39.

2. Self-Study Information

Competency 1.18 and 1.19 addresses the knowledge of the theory, construction and operation of steam systems. Competency 1.18 at a familiarity level and Competency 1.19 at a working level of knowledge.

The supporting material for the Self-Study Activities include the following documents:

- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2.
- DOE Topical Area Mechanical Science Study Guide (SR-TA-MES-SSG-01) Chapter Piping.
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101)
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102)
- Westinghouse Savannah River Company High Level Waste Operator Training Heat Transfer and Fluid Flow Study Guide (NWMOG009.H0103)
- Westinghouse Savannah River Company High Level Waste Operator Training Program Applied Heat Transfer and Fluid Flow Study Guide (WGACFA06)

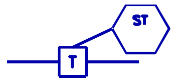
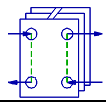
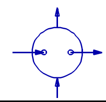
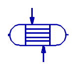
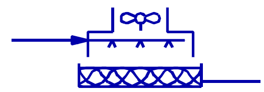
- Combustion Engineering (1967). Steam Tables Properties of Saturated and Superheated Steam - From 0.08865 to 15,500 LB per SQ IN. Absolute Pressure (Eleventh Printing). Windsor, CT: Combustion Engineering, Inc. ISBN 1-500-00002610. Call # TJ270.S8 1967.
- Granet, Irving, P.E. (1985). Thermodynamics and Heat Power. Reston, VA: Reston Publishing Company. ISBN 0-8359-7674-2. Chapter 4, Properties of Liquids and Gases.
- Keenan, J. H., F. G. Keyes, P. G. Hill, and J. G. Moore (1969). Steam Tables-Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases. New York, NY: John Wiley & Sons, Inc.
- Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.

The Steam Tables and Mollier Diagram are tables of thermodynamic properties and provide accurate data of various substances. Thermodynamic data in these tables are equilibrium data, and charts plotted from these data can represent only the equilibrium states.

The research on the thermodynamic properties of water has been carried out throughout the world and as a result of this research extensive tables of water properties have been published known as the steam tables. This study is made up of tables which cover the thermodynamic properties of water, ice, and steam. They include their transport properties, viscosity, and thermal conductivity.

The Mollier Chart is a plot on h-s coordinates of the thermodynamic properties of a substance where h = enthalpy and s = entropy. The Mollier Chart is particularly suited to obtaining properties, in describing flow, or describing constant-pressure processes. If a process is not reversible, then only its end states can be shown on a thermodynamic diagram such as the Mollier Chart.

Figure 42 MISCELLANEOUS STEAM LINE SYMBOLS

Steam Trap			
Plate type heat exchanger		Shell and tube heat exchanger	
Cooler or condenser		Cooling tower	

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **K&S 1.18-S.1.a.** refer to:
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Steam Systems; Chapter Valves; Chapter Valve Actuators and Positioners.
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Steam Systems.
- Westinghouse Savannah River Company High Level Waste Operator Training Heat Transfer and Fluid Flow Study Guide (NWMOG009.H0103) Chapter Forms of Energy; Chapter Heating and Cooling Processes in Fluids.

b. For Supporting Knowledge and Skills **K&S 1.18-S.1.b.** refer to:
- Granet, Irving, P.E. (1985). Thermodynamics and Heat Power. Reston, VA: Reston Publishing Company. ISBN 0-8359-7674-2. Chapter 4, Properties of Liquids and Gases.
- Keenan, J. H., F. G. Keyes, P. G. Hill, and J. G. Moore (1969). Steam Tables-Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases. New York, NY: John Wiley & Sons, Inc.
- Combustion Engineering (1967). Steam Tables Properties of Saturated and Superheated Steam - From 0.08865 to 15,500 LB per SQ IN. Absolute Pressure (Eleventh Printing). Windsor, CT: Combustion Engineering, Inc. ISBN 1-500-00002610. Call # TJ270.S8 1967.

c. For Supporting Knowledge and Skills **K&S 1.18-S.1.c.** refer to:
   - Granet, Irving, P.E. (1985). Thermodynamics and Heat Power. Reston, VA: Reston Publishing Company. ISBN 0-8359-7674-2. Chapter 4, Properties of Liquids and Gases.
   - Keenan, J. H., F. G. Keyes, P. G. Hill, and J. G. Moore (1969). Steam Tables-Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases. New York, NY: John Wiley & Sons, Inc.
   - Combustion Engineering (1967). Steam Tables Properties of Saturated and Superheated Steam - From 0.08865 to 15,500 LB per SQ IN. Absolute Pressure (Eleventh Printing). Windsor, CT: Combustion Engineering, Inc. ISBN 1-500-00002610. Call # TJ270.S8 1967.

d. For Supporting Knowledge and Skills **K&S 1.18-S.1.d.** refer to:
   - DOE Topical Area Mechanical Science Study Guide (SR-TA-MES-SSG-01) Chapter Piping; Chapter Valves.
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Steam Systems; Chapter Valves; Chapter Valve Actuators and Positioners.
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Steam Systems.

e. For Supporting Knowledge and Skills **K&S 1.18-S.1.e.** refer to:
   - DOE Topical Area Mechanical Science Study Guide (SR-TA-MES-SSG-01) Chapter Piping; Chapter Valves.
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Steam Systems; Chapter Valves; Chapter Valve Actuators and Positioners.
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Steam Systems.
   - Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter 7 Piping, Valves, Gaskets, and Packing.

f. For Supporting Knowledge and Skills **K&S 1.18-S.1.f.** refer to:
   - DOE Topical Area Mechanical Science Study Guide (SR-TA-MES-SSG-01) Chapter Piping.

g. For Supporting Knowledge and Skills **K&S 1.18-S.1.g.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Program Applied Heat Transfer and Fluid Flow Study Guide (WGACFA06)

h. For Supporting Knowledge and Skills **K&S 1.19-T.1.a.** refer to:
   - Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210. Chapter 7 Piping, Valves, Gaskets, and Packing.
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0101) Chapter Steam Systems.
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Steam Systems.

4. Practice Exercise

a. What is the formula for quality? (K&S 1.18-S.1.a.)

b. Excessive moisture accompanying the steam leaving the steam generator is known as? (K&S 1.18-S.1.a.)

1) Carryover

2) Condensation

3) Enthalpy

4) Steam quality

c. Describe the purpose, components, and the relative location of a drip leg. (K&S 1.18-S.1.e.)

d. Describe the operation of the components in a drip leg during startup of a steam line. (K&S 1.18-S.1.e.)

e. Describe the purpose and the relative location of a moisture separator. (K&S 1.18-S.1.e.)

f. Discuss site specific procedures to isolation of a portion of a steam system including all associated precautions. (K&S 1.18-S.1.f.)

g. List four types of steam traps. (K&S 1.19-T.1.a.)

1)

2)

3)

4)

h. Describe the operations of a thermostatic steam trap. (K&S 1.19-T.1.a.)

The trap consists of a bellows and valve arrangement. The bellows is filled with a volatile liquid that expands and contracts with temperature changes. The valve is operated by the bellows. When hot steam is in the trap, the bellows expands and closes the valve. As cooler condensate enters the trap, it collects around the bellows and the bellows contracts. When the bellows contracts it opens the discharge valve and the condensate drains from the trap.

i. List two purposes of a steam trap. (K&S 1.19-T.1.a.)

1.

2.

5. Practice Exercise Answers

a. What is the formula for quality? (K&S 1.18-S.1.a.)

$$x = \frac{\text{mass of steam}}{\text{mass of (steam and water) mixture}}$$

b. Excessive moisture accompanying the steam leaving the steam generator is known as? (K&S 1.18-S.1.a.)

1) Carryover

2) Condensation

3) Enthalpy

4) Steam quality

c. Describe the purpose and the relative location of a drip leg. (K&S 1.18-S.1.e.)

Drip legs are located at the low points in steam lines. The consist of piping, steam traps, and steam trap bypass valves. They are used to remove condensation from the steam lines.

d. Describe the operation of the components in a drip leg during startup of a steam line. (K&S 1.18-S.1.e.)

Isolate the steam traps before beginning the steam line warmup, this to prevent excessive flow through the steam trap causing damage to the trap. Open the steam trap bypass valves fully to allow condensate to drain from the lines. Monitor the steam trap bypass valve outlet for dry steam. When dry steam emitted from the steam trap bypass valve, close the steam trap bypass valves and open the inlet and outlet valves to the steam trap. *This is a generic description ensure all site approved procedures are followed.*

e. Describe the purpose and the relative location of a moisture separator. (K&S 1.18-S.1.e.)

   Moisture separators are located in the top of a steam generator. They are designed to remove excess moisture from the steam before it enters the steam lines.

f. Discuss site specific procedures to isolation of a portion of a steam system including all associated precautions: (K&S 1.18-S.1.f.)

   Locate a copy of site specific procedures for isolation of a portion of a steam system.

   Identify key requirements.

   List all associated precautions and describe the basis associated with the step.

g. List four types of steam traps. (K&S 1.19-T.1.a.)

   1) Bucket trap

   2) Inverted bucket trap

   3) Ball float trap

   4) Thermostatic steam trap

   5) Thermodynamic Disc trap

   6) Impulse trap

h. Describe the operations of a thermostatic steam trap. (K&S 1.19-T.1.a.)

   The trap consists of a bellows and valve arrangement. The bellows is filled with a volatile liquid that expands and contracts with temperature changes. The valve is operated by the bellows. When hot steam is in the trap, the bellows expands and closes the valve. As cooler condensate enters the trap, it collects around the bellows and the bellows contracts. When the bellows contracts it opens the discharge valve and the condensate drains from the trap.

i. List two purposes of a steam trap. (K&S 1.19-T.1.a.)

- Remove excess condensate
- Remove non-condensible gases
- Prevent equipment damage due to excessive water (erosion and corrosion)
- Prevent damage due to water hammer

U. **Competency 1.20**

Facility maintenance management (FAC# 1.3) personnel shall demonstrate a familiarity level knowledge of a typical diesel engine including support systems.

1. Supporting Knowledge and Skills

   a. Using a cutaway drawing of a typical diesel engine, identify the main components.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.

   b. Discuss the underlying principle of the operation of a diesel engine.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Fundamentals of the Diesel Cycle.

   c. Differentiate between two-stroke and four-stroke (two-cycle and four cycle) engines.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Fundamentals of the Diesel Cycle.

   d. Discuss the purpose of diesel engine support systems.
      DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.

V. **Competency 1.21**

Mechanical systems (FAC# 1.4) personnel shall demonstrate a working level knowledge of a typical diesel engine including support systems.

1. Supporting Knowledge and Skills

   a. Using a cutaway drawing of a typical diesel engine, identify and discuss the purpose of the major parts, including:

      - Pistons
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.
      - Connecting rods
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.
      - Crank shaft
        DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.

- Injectors
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.
- Main bearings
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.
- Cylinder liners
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.
- Cooling water jackets
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.

b. Differentiate between two-stroke and four-stroke (two-cycle and four-cycle) engines.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Fundamentals of the Diesel Cycle.

c. Discuss the ignition principle in a diesel engine.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Fundamentals of the Diesel Cycle.

d. Discuss the purpose and principle of operation of a diesel engine injector.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Speed, Fuel Controls, and Protection.

e. Discuss the purpose of the following diesel engine support systems:

- Cooling water
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.
- Lubrication
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.
- Fuel oil
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals and Chapter Diesel Engine Speed, Fuel Controls, and Protection.
- Scavenging air
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.

- Starting systems
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.

f. Using a cutaway drawing of a typical diesel engine, identify the following systems and trace their flowpaths:

- Fuel oil
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals and Chapter Diesel Engine Speed, Fuel Controls, and Protection.
- Lubrication
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.
- Cooling water
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.
- Air
  DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.

g. Discuss the purpose of a blower or turbo charger for a diesel engine.
   DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2, Module 1, Chapter Diesel Engine Fundamentals.

2. Self-Study Information

Competency 1.20 and 1.21 address the knowledge of the principles associated with diesel engines and support systems. Competency 1.20 at a familiarity level and Competency 1.21 at a working level of knowledge.

The supporting material for the Self-Study Activities include the following documents:

- DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2.
- Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102)

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Summary section of this competency.

a. For Supporting Knowledge and Skills **K&S 1.20-U.1.a. and K&S 1.21-V.1.a.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Diesel Engine Speed, Fuel Controls, and Protection; Chapter Diesel Engine Speed, Fuel Controls, and Protection.

b. For Supporting Knowledge and Skills **K&S 1.20-U.1.b.**1 refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Diesel Engines; Chapter Fundamentals of the Diesel Engine Combustion Cycle; Chapter Diesel Engine Speed, Fuel Controls, and Protection.

c. For Supporting Knowledge and Skills **K&S 1.20-U.1.c. and K&S 1.21-V.1.b.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Fundamentals of the Diesel Engine Combustion Cycle.

d. For Supporting Knowledge and Skills **K&S 1.20-U.1.d. and K&S 1.21-V.1.e.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Diesel Engines; Chapter Diesel Engine Speed, Fuel Controls, and Protection.

e. For Supporting Knowledge and Skills **K&S 1.21-V.1.c.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Fundamentals of the Diesel Engine Combustion Cycle.

f. For Supporting Knowledge and Skills **K&S 1.21-V.1.d.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Diesel Engine Speed, Fuel Controls, and Protection.

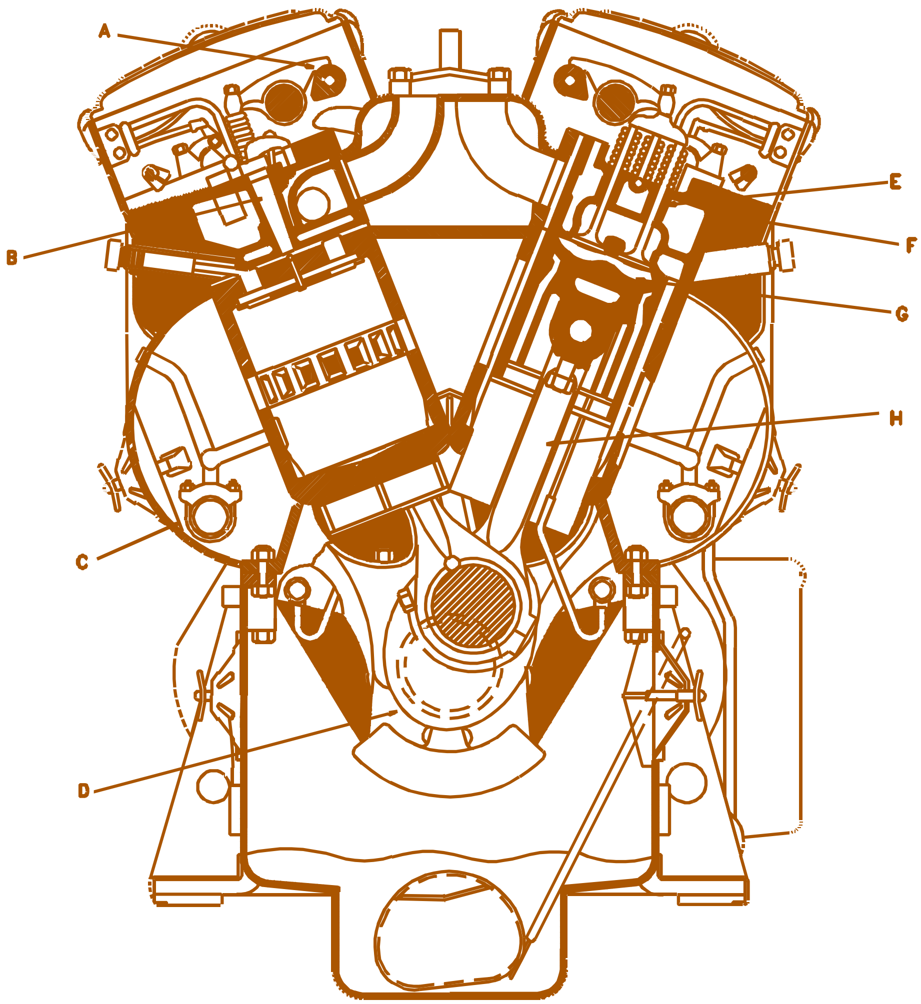
g. For Supporting Knowledge and Skills **K&S 1.21-V.1.f.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Diesel Engines; Chapter Diesel Engine Speed, Fuel Controls, and Protection.

h. For Supporting Knowledge and Skills **K&S 1.21-V.1.g.** refer to:
   - Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102) Chapter Diesel Engines.

4. Practice Exercise

a. Match the diesel component purpose in column A with the name of the diesel component in column B. Use the column B answers one time only. Ignore any response in column B not identified in column A. (K&S 1.20-U.1.a.) (K&S 1.21-V.1.a.)

Column A	Column B
__ 1. Supports the weight of the crankshaft and provides a cooled and lubricated surface to allow smooth rotation.	a. Connecting rods
	b. Cooling water jackets
__ 2 An insert to the cylinder block provides a smooth surface for the piston to travel in.	c. Crank shaft
	d. Cylinder liners
__ 3. Converts the up and down motion (reciprocating) of the piston into the rotary motion of the crankshaft.	e. Injectors
	f. Main bearings
__ 4 Moves up and down inside the cylinder liner or sleeve, driven by the force of the expanding combustion gases.	g. Pistons



b. Match the diesel component purposes below with the components shown in the cutaway figure above. Use the components in the cutaway one time only. Ignore any component in the figure not listed below. (K&S 1.20-U.1.a.) (K&S 1.21-V.1.a.)

__ 1. Transforms the energy of the expanding gases into mechanical energy.

__ 2. Couples the piston to the crankshaft.

__ 3. Transforms linear motion into rotational energy of the pistons.

__ 4. Consists of coolant passages in the block, heads, and cylinders to allow for the removal of heat generated by friction and combustion.

c. Describe how a diesel engine converts the chemical energy of the fuel into a useful energy. (K&S 1.20-U.1.b.)

d. Which type of diesel engine is more effective at using energy from the combustion process? (K&S 1.20-U.1.c.) (K&S 1.21-V.1.b.)

e. For each of the statements below determine if the statement represents a two-stroke (two-cycle), a four-stroke (four cycle), or both cycles and name the event. (K&S 1.20-U.1.c.) (K&S 1.21-V.1.b.)

2 stroke - 4 stroke ________ The piston passes top dead center (TDC), the intake valve(s) open and fresh air is admitted into the cylinder.

2 stroke - 4 stroke ________ Near TDC the fuel is injected by the injectors and the fuel starts to burn, further heating the gasses in the cylinder.

2 stroke - 4 stroke ________ As the piston approaches BDC the exhaust valves or ports open and the exhaust gasses start to flow out of the cylinder.

2 stroke - 4 stroke ________ The piston passes TDC and the expanding gasses force the piston down, rotating the crankshaft.

f. State the purpose of scavenging air diesel engine support systems. (K&S 1.20-U.1.d.) (K&S 1.21-V.1.e.)

g. State the purpose of fuel oil diesel engine support systems. (K&S 1.20-U.1.d.) (K&S 1.21-V.1.e.)

h. Which of the following statements below best describes why the diesel fuel in a diesel engine ignites? (K&S 1.21-V.1.c.)

1) High temperature from a spark

2) High temperature from friction

3) High pressure from the diesel fuel injector

4) High temperature and pressure from the compression of the piston

i. State the name of the diesel component that directs diesel fuel into the cylinder. (K&S 1.21-V.1.d.)

j. Why is the diesel fuel sprayed into the cylinder? (K&S 1.21-V.1.d.)

k. Number the applicable components below in the sequential order that best describes the flowpath of a typical diesel engine lubrication system. (K&S 1.21-V.1.f.)

__ 1) crankcase / sump

__ 2) cooler

__ 3) filter

__ 4) fuel oil injectors

__ 5) oil pump

__ 6) main bearings

l. Which type of diesel engine commonly uses the following components: (K&S 1.21-V.1.g.)

   1) Blower

   2) Turbo charger

m. Which of the following statements best describes the operation of the a diesel engine blower. (K&S 1.21-V.1.g.)

   1) Two rotating rotors in the air intake system are driven by gears connected to the crankshaft of the diesel engine.

   2) The exhaust gases are forced through a turbine which turns an impeller in the air intake system.

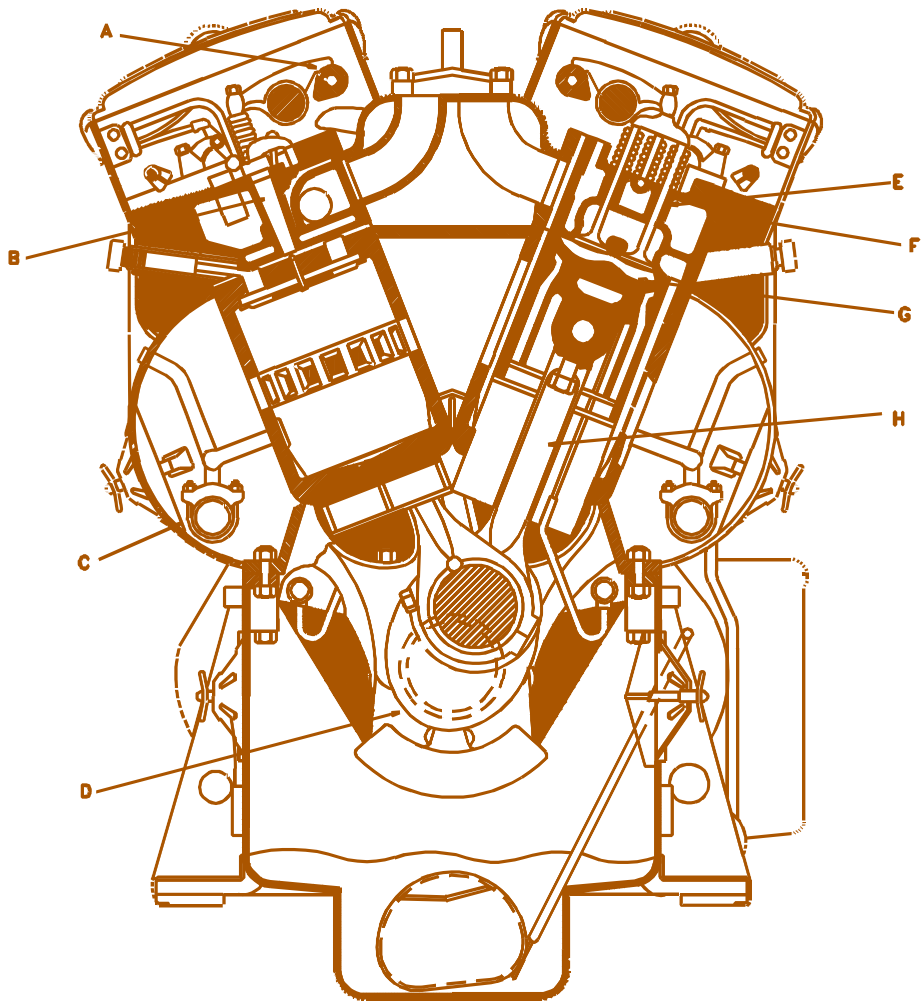
   3) Two rotating rotors in the air intake system are driven by gears connected to a turbine spinning from exhaust gases leaving the diesel engine.

   4) An impeller in the air intake system is driven by an electrical motor.

5. Practice Exercise Answers

a. Match the diesel component purpose in column A with the name of the diesel component in column B. Use the column B answers one time only. Ignore any response in column B not identified in column A. (K&S 1.20-U.1.a.) (K&S 1.21-V.1.a.)

Column A	Column B
_f_ 1. Supports the weight of the crankshaft and provides a cooled and lubricated surface to allow smooth rotation.	a. Connecting rods
	b. Cooling water jackets
_d_ 2 An insert to the cylinder block provides a smooth surface for the piston to travel in.	c. Crank shaft
	d. Cylinder liners
_a_ 3. Converts the up and down motion (reciprocating) of the piston into the rotary motion of the crankshaft.	e. Injectors
	f. Main bearings
_g_ 4 Moves up and down inside the cylinder liner or sleeve, driven by the force of the expanding combustion gases.	g. Pistons



b. Match the diesel component purposes below with the components shown in the cutaway figure above. Use the components in the cutaway one time only. Ignore any component in the figure not listed below. (K&S 1.20-U.1.a.) (K&S 1.21-V.1.a.)

_G_ 1. Transforms the energy of the expanding gases into mechanical energy.

_H_ 2. Couples the piston to the crankshaft.

_D_ 3. Transforms linear motion into rotational energy of the pistons.

_C_ 4. Consists of coolant passages in the block, heads, and cylinders to allow for the removal of heat generated by friction and combustion.

c. Describe how a diesel engine converts the chemical energy of the fuel into a useful energy. (K&S 1.20-U.1.b.)

The fuel is burned causing a chemical reaction. Energy is released in the form of heat. The heat causes the combustion gases to expand. The expansion of the gases is trapped by the piston, the cylinder, and the block head. The expanding gases force the pistons to move. The linear motion (or reciprocating up and down) is converted to rotational motion by the crankshaft. The rotational motion can be used to drive a transmission or electrical generator.

d. Which type of diesel engine is more effective at using energy from the combustion process? (K&S 1.20-U.1.c.) (K&S 1.21-V.1.b.)

4 stroke converts 42% to useful energy (28% rejected to cooling system and 30% rejected out the exhaust)
2 stroke converts 38% to useful energy (30% rejected to cooling system and 32% rejected out the exhaust)

e. For each of the statements below determine if the statement represents a two-stroke (two-cycle), a four-stroke (four cycle), or both cycles and name the event. (K&S 1.20-U.1.c.) (K&S 1.21-V.1.b.)

2 stroke - **4 stroke** _intake_ The piston passes top dead center (TDC), the intake valve(s) open and fresh air is admitted into the cylinder.

2 stroke - 4 stroke _injection_ Near TDC the fuel is injected by the injectors and the fuel starts to burn, further heating the gasses in the cylinder.

2 stroke - 4 stroke _exhaust_ As the piston approaches BDC the exhaust valves or ports open and the exhaust gasses start to flow out of the cylinder.

2 stroke - 4 stroke _power_ The piston passes TDC and the expanding gasses force the piston down, rotating the crankshaft.

f. State the purpose of scavenging air diesel engine support systems. (K&S 1.20-U.1.d.) (K&S 1.21-V.1.e.)

Removes the spent exhaust gases and cools the cylinder.

g. State the purpose of fuel oil diesel engine support systems. (K&S 1.20-U.1.d.) (K&S 1.21-V.1.e.)

   Stores and delivers clean, cool fuel oil

h. Which of the following statements below best describes why the diesel fuel in a diesel engine ignites? (K&S 1.21-V.1.c.)

   1) High temperature from a spark

   2) High temperature from friction

   3) High pressure from the diesel fuel injector

   4) High temperature and pressure from the compression of the piston

i. State the name of the diesel component that directs diesel fuel into the cylinder. (K&S 1.21-V.1.d.)

   Diesel engine injector.

j. Why is the diesel fuel sprayed into the cylinder? (K&S 1.21-V.1.d.)

   In order to burn the fuel must be vaporized first, by spraying the fuel into the cylinder the fuel is vaporized easier allowing it to burn more efficiently.

k. Number the applicable components below in the sequential order that best describes the flowpath of a typical diesel engine lubrication system. (K&S 1.21-V.1.f.)

   _1 1) crankcase / sump

   _4 2) cooler

   _3 3) filter

   __4) fuel oil injectors

   _2 5) oil pump

   _5 6) main bearings

l. Which type of diesel engine commonly uses the following components: (K&S 1.21-V.1.g.)

   1) Blower 2 stroke

   2) Turbo charger 4 stroke

m. Which of the following statements best describes the operation of the a diesel engine blower. (K&S 1.21-V.1.g.)

   1) **Two rotating rotors in the air intake system are driven by gears connected to the crankshaft of the diesel engine.**

   2) The exhaust gases are forced through a turbine which turns an impeller in the air intake system.

   3) Two rotating rotors in the air intake system are driven by gears connected to a turbine spinning from exhaust gases leaving the diesel engine.

   4) An impeller in the air intake system is driven by an electrical motor.

This page is intentionally blank.

W. **Competency 1.22**

Environmental compliance (FAC# 1.5), Instrumentation and controls (FAC# 1.17), Nuclear safety system (FAC# 1.11), and Project management (FAC# 1.1) personnel shall demonstrate a familiarity level knowledge of piping and instrumentation drawings (P&ID).

1. Supporting Knowledge and Skills

   a. Given an engineering print, read and interpret the following information:

      - Title block
      - Notes
      - Legend
      - Revision block
      - Drawing grid

      DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 1, Chapter Introduction to Print Reading.

   b. Given a piping and instrumentation drawing, identify/interpret the symbols used for system components including the following as a minimum:

      - Valves
      - Valve operators
      - Pumps
      - Eductors and ejectors
      - Heat exchangers
      - Filters/Strainers
      - Fans
      - Compressors
      - Types of lines
      - Instruments
      - Indicators
      - Controllers

      DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Engineering Fluids Diagrams and Prints.

c. Identify how valve conditions (open/closed) are depicted.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Reading Engineering P&IDs.

d. Determine system flowpaths for a given valve lineup.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter P&ID Print Reading Example.

e. Given a process and instrumentation diagram and the technical specifications for a process system, describe the purpose of the system and the major flowpaths.

f. Given a process and instrumentation diagram and the technical specifications for a process system, describe the function of each of the major components of the system.

X. Competency 1.23

Facility representatives (FAC# 1.21) and Mechanical systems (FAC# 1.22) personnel shall demonstrate a working level knowledge of read and interpret mechanical diagrams associated with instrumentation and control systems including:

- **As-built drawings**
- **Piping and Instrumentation Diagrams (P&ID)**

1. Supporting Knowledge and Skills

a. Given an engineering print, read and interpret the following information:

- Title block
- Notes
- Legend
- Revision block
- Drawing grid

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 1, Chapter Introduction to Print Reading.

b. Given an engineering piping and instrument drawing, identify the symbols used for:

- Valves
- Valve operators
- Pumps
- Eductors and ejectors
- Heat exchangers
- Filters/Strainers
- Fans
- Compressors
- Types of lines
- Instruments
- Indicators
- Controllers

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Engineering Fluids Diagrams and Prints.

c. Identify the symbols used on engineering P&IDs to denote the location of instruments, indicators, and controllers.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Reading Engineering P&IDs.

d. Identify how valve conditions are depicted.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Reading Engineering P&IDs.

e. Determine system flowpath(s) for a given valve lineup.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter P&ID Print Reading Example.

f. Given a fluid power type drawing, determine the operation or resultant action of the stated component when hydraulic pressure is applied/removed.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Fluid Power P&IDs.

g. Discuss the origin and purpose of "as-built drawings."

Y. Competency 1.24

Construction management and engineering (FAC# 1.7), EH Residents (FAC# 1.14), Facility maintenance management (FAC# 1.19), and Instrumentation and control (FAC# 1.21) personnel shall demonstrate the ability to read and interpret mechanical diagrams associated with instrumentation and control systems including:

- **Construction drawings**
- **As-built drawings**
- **Piping and Instrumentation Diagrams (P&ID)**
- **Assembly drawings**

1. Supporting Knowledge and Skills

a. Given an engineering print, read and interpret the following information:

- Title block
- Notes
- Legend
- Revision block
- Drawing grid

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 1, Chapter Introduction to Print Reading.

b. Given a piping and instrumentation drawing, identify/interpret the symbols used for system components including the following as a minimum:

- Valves
- Valve operators
- Pumps
- Eductors and ejectors
- Heat exchangers

- Filters/Strainers
- Fans
- Compressors
- Types of lines
- Instruments
- Indicators
- Controllers

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Engineering Fluids Diagrams and Prints.

c. Identify the symbols used to denote the location of instruments, indicators, and controllers.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Reading Engineering P&IDs.

d. Identify how valve conditions are depicted.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Reading Engineering P&IDs.

e. Determine the system flowpath for a given valve lineup.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter P&ID Print Reading Example.

f. Given a fluid power drawing, determine the operation or resultant action of the stated component when hydraulic pressure is applied/removed.

DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93) Volume 1 of 2, Module 2, Chapter Fluid Power P&IDs.

2. Self-Study Information

Competency 1.22, 1.23, and 1.24 address the knowledge of the reading and interpreting Piping and Instrumentation Diagrams (P&IDs). Competency 1.22 at a familiarity level, Competency 1.23 at a working level of knowledge, and Competency 1.24 at a demonstrate the ability level.

The supporting material for the Self-Study Activities include the following documents:

- DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93), Volume 1 of 2.
- DOE-STD-1073-93-Pt.1 (1993). Guide for Operational Configuration Management Program
- Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100)
- American National Standards Institute (1979). <u>Graphic Symbols for Fluid Power Diagrams (ANSI Y32.10)</u>. New York, NY: American National Standards Institute
- Anders, James E. Sr. (1983). <u>Industrial Hydraulics Troubleshooting</u>. New York, NY: McGraw-Hill Book Company. ISBN 0-07-001592-9.
- Palmquist, Roland (1979). <u>Answers on Blue Print Reading</u>. Indianapolis, IN: Theodore Audel & Co. ISBN 0-672-23283-9. Chapter 14 Graphical symbols

> Most books on blueprint reading and drafting focus the books on architectural, pictorial, orthographic, and working drawings. When looking for a book ensure the covers graphical symbols. Ensure that site specific symbols and prints are used when studying and interpreting mechanical prints.

<u>Title Block</u>

The title block of a drawing is usually located in the lower right hand corner. Figure 43 is an example of a title block of a drawing. The title block of a drawing contains the following information:

- Drawing title
- Drawing number
- Location, site, or vendor issuing the drawing
- Design, review, and approval signatures
- Reference block

The drawing title and number are used for identification and filing purpose. The number is unique to the drawing and is comprised of a code that contains information about the drawing such as the site, system, and type of drawing.

The design, review and approval section provides information as to when and by whom the system/component was designed and when and by whom the drawing was drafted and verified for final approval.

The reference block lists other drawings that are related to the system/component or it can list other drawings that are cross-referenced on the drawing. The reference block can be helpful in tracking down additional information on the system or component.

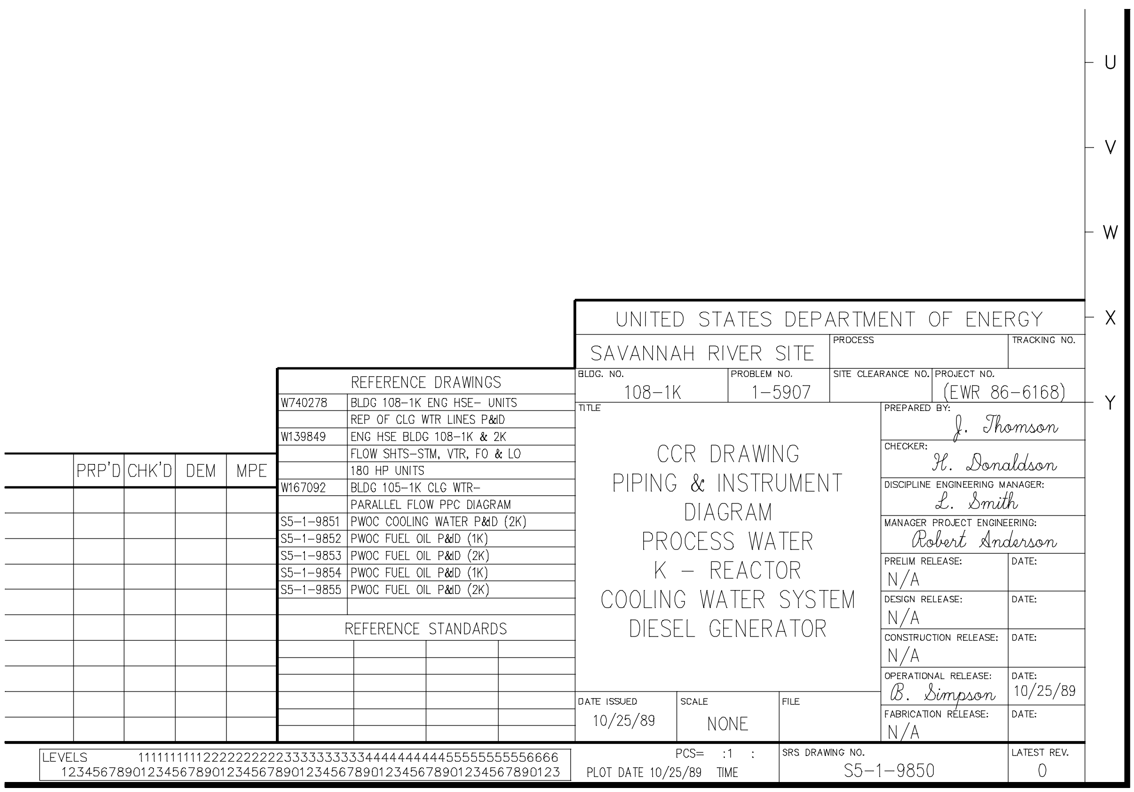


Figure 43 Title Block

Grid System

To help locate a specific point on a print, most drawings have a grid system. The grid can consist of letters, numbers, or both that run horizontally and vertically around the drawing as illustrated in Figure 44. The drawing is divided into smaller blocks, each having an unique two letter or number identifier. The grid system of a drawing allows information to be more easily located using the coordinates provided by the grid.

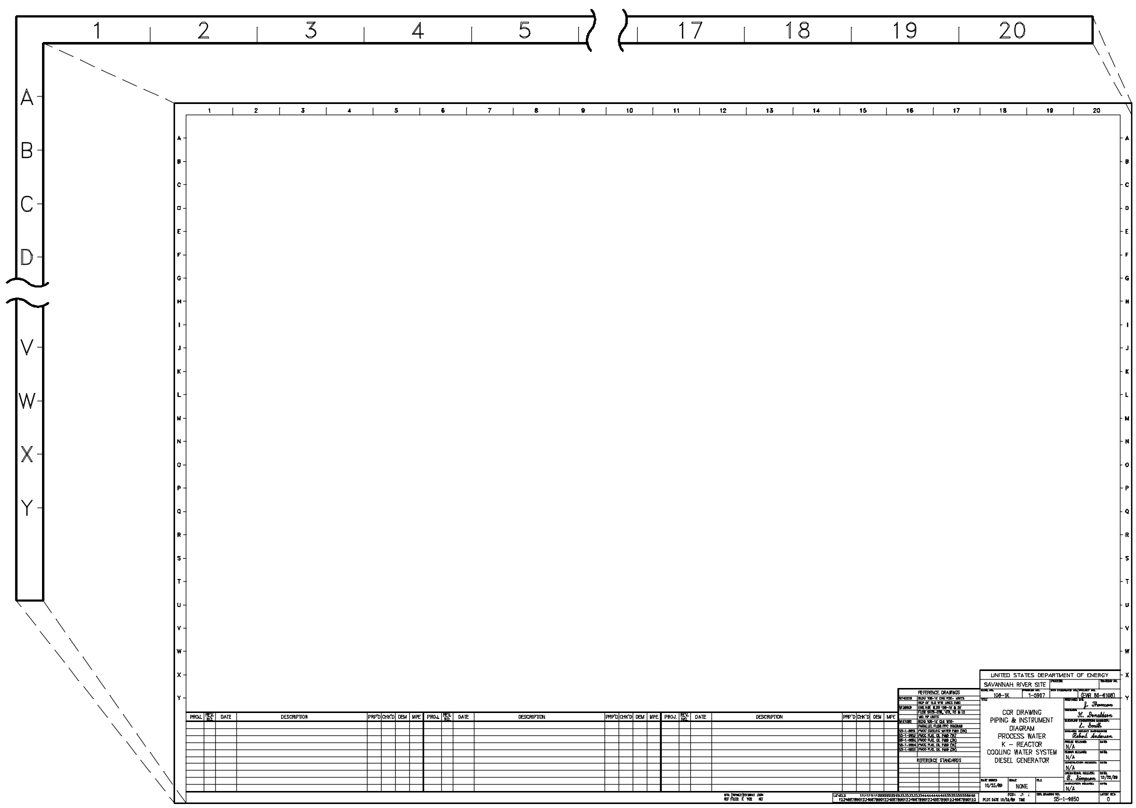


Figure 44 Example of a Grid

Revision Block

The revision block of a drawing provides the revision number, a title or summary of the revision, and the date of the revision, for each revision. When a drawing is first issued, it is revision zero. As each revision is made to the drawing, an entry is placed in the revision block. As the system or component is modified, and the drawing is updated to reflect the changes, the revision number is increased by one, and the revision number in the revision block is changed to indicated the new revision number. Figure 45 is an example of a revision block.

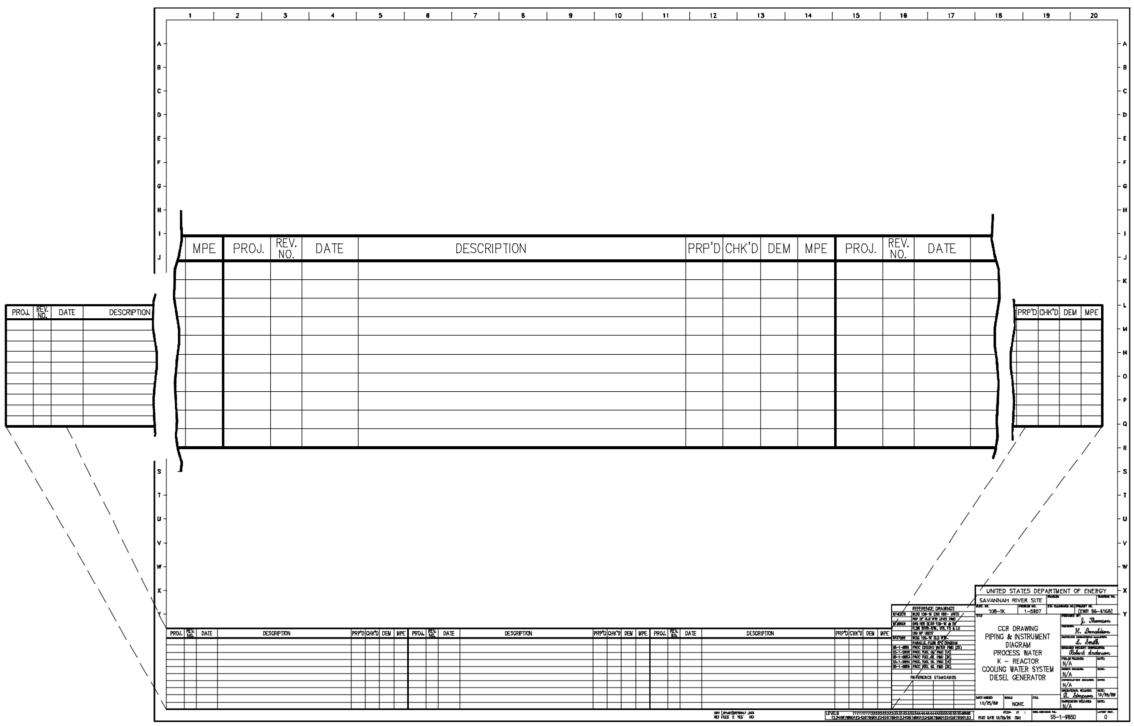


Figure 45 Revision Block

Notes and Legend

The notes and legends section of a drawing provide explanations of special symbols or conventions used on the drawing and any additional information the designer or draftsman felt was necessary to better understand the drawing. Because of the importance of understanding all the symbols and conventions used on a drawing, the notes and legends section must be reviewed before reading a drawing. Figure 46 illustrates a notes and legend section of a drawing.

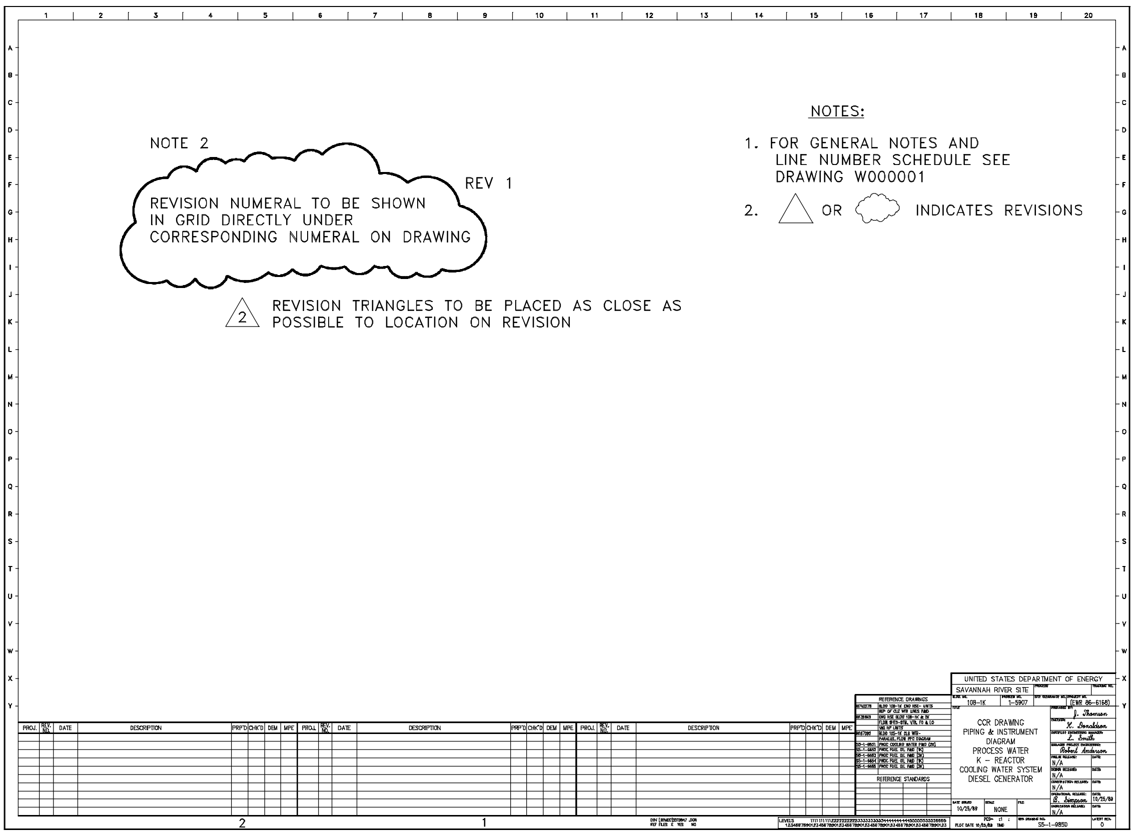


Figure 46 Methods of Denoting Changes

"As-built" drawings

The purpose of "as-built" drawings is to document the actual physical configuration of a system including piping, valves, controllers switches, gauges, etc, for example. The as-built drawing is usually done to verify that what was installed agrees with what is on the drawings. As-found drawings are similar except you are verifying what is found in the field when it is walked-down. If there are any discrepancies between the two, they are reconciled according to site standards.

Symbols

To read and interpret P&ID's, the reader must learn the meaning of the symbols. The following symbols described are those most commonly used in mechanical systems. For any additional symbology, the reader can obtain the appropriate standards used at his or her facility.

Figure 47 and Figure 48 illustrate symbols used to identify specific types of pipe fittings and connections.

Figure 47 PIPING SYMBOLS

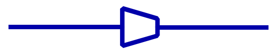
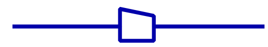
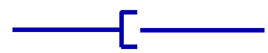
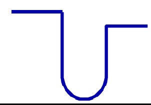
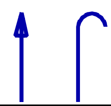
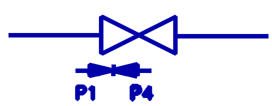
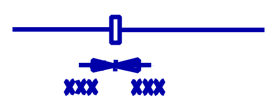
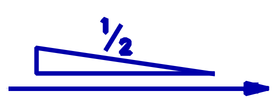
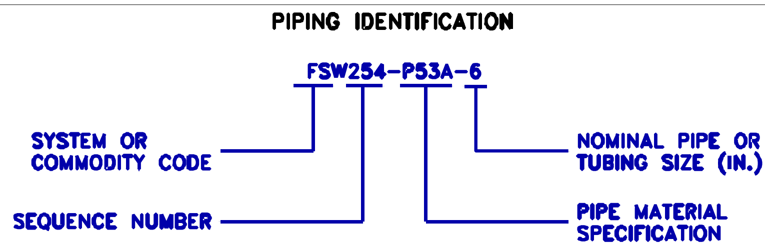
Concentric reducer		Eccentric reducer	
Welded cap		Screw cap	
Hose cap		Quick disconnect	
Removable spool		Flexible connect	
Blind flange		Loop seal	
Funnel		Vent	

Figure 48 PIPING SYMBOLS

Piping Change		Piping Change	
Slope		Dupont Valve Code	

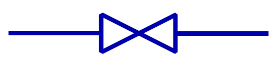
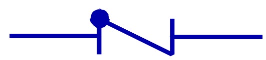
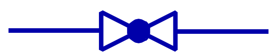
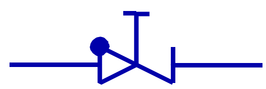
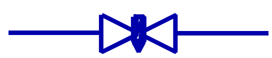
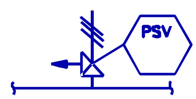
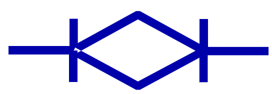
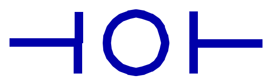
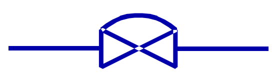


Valve Symbols

Valves are used to control the direction, flow rate, and pressure of fluids. Figure 49 shows the symbols that depict major valve types and other flow control devices used at DOE facilities.

Different symbols are used to represent individual valve types. This is necessary because of the different ways each valve type affects system operation. On an actual P&ID, individual valves will be further identified by a specific valve number.

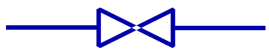
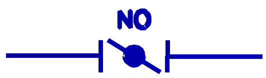
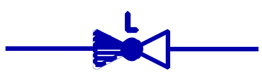
Figure 49 VALVE SYMBOLS

Gate valve		Check valve	
Globe valve		Stop check valve	
Needle valve		Safety valve	
Plug valve		Ball valve	
Diaphragm valve		Butterfly valve	

Standards and Conventions for Valve Status

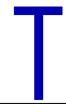
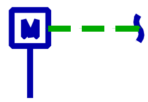
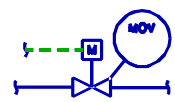
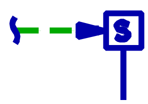
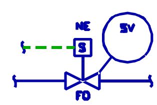
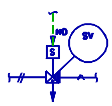
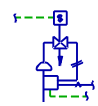
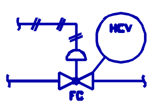
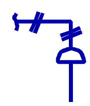
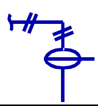
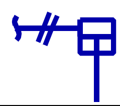
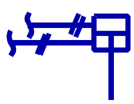
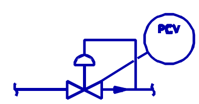
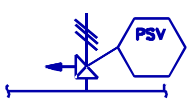
Before a P&ID can be properly interpreted, the basic conventions used to denote valve status and failure modes must be understood. Figure 50 illustrates the symbols used. Unless otherwise stated, P&IDs indicate valves in their "normal" positions. This is usually interpreted as the normal or primary flowpath for the system. An exception is safety systems, which are normally shown in their standby or non-accident condition.

Figure 50 VALVE POSITION AND STATUS

Open (Gate) valve		Closed (Gate) valve	
Lock open (Gate) valve		Lock closed (Gate) valve	
Normally open (Butterfly) valve		Normally closed (Butterfly) valve	
Throttled and locked (Globe) valve			

Valve operators are used to allow the remote operation of valves. Figure 51 shows the symbols for common valve operators. If no valve operator symbol is shown, it may be assumed that the valve is equipped with only a handwheel for manual operation.

Figure 51 VALVE ACTUATORS

Unclassified actuator		Hand actuator	
Rotary motor		Motor operated 2-way globe valve	
Single solenoid		Single solenoid 2-way valve normally energized (fail open)	
3-way Pilot valve		Pneumatic diaphragm or spring return piston with electro-pneumatic positioner and solenoid valve	
Diaphragm operated 2-way globe valve (fail closed)		Pneumatic diaphragm	
Diaphragm pressure balanced		Pneumatic cylinder single acting	
Pneumatic cylinder double acting		Pressure reducing regulator with external pressure tap	
Pressure safety valve angle patterned			

Pumps (Figure 52), compressors (Figure 53), filters/strainers (Figure 54), heat exchangers (Figure 55), ventilation systems (Figure 56), dampers (Figure 57), and steam system components (Figure 58) are major components that are contained in mechanical systems. The figures below show the symbols for these major components.

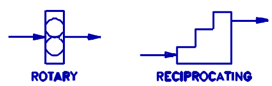
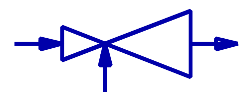
Figure 52 PUMP SYMBOLS			
Positive displacement Pumps		Centrifugal Pump	
		Eductor	

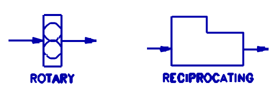
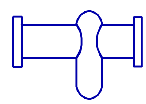
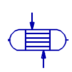
Figure 53 COMPRESSED AIR SYMBOLS			
Compressors		Aftercooler with moisture separator	
Cooler or condenser		Gas cylinder	

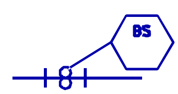
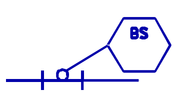
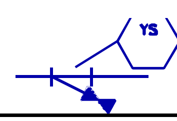
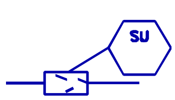
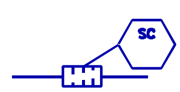
Figure 54 FILTERS AND STRAINERS			
Filter		Twin Basket Strainer	
Single Basket Strainer		Y-type strainer	
Temporary startup strainer		Screen type strainer	

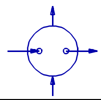
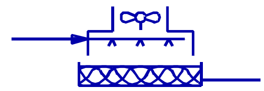
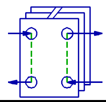
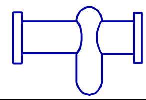
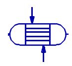
Figure 55 HEAT EXCHANGER SYMBOLS			
Shell and tube heat exchanger		Cooling tower	
Plate type heat exchanger		Aftercooler with moisture separator	
Cooler or condenser			

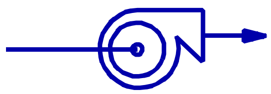
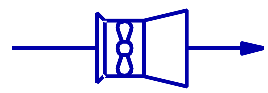
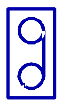
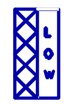
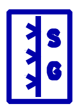
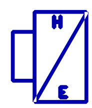
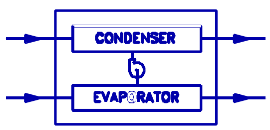
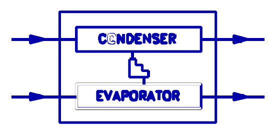
Figure 56 VENTILATION SYMBOLS			
Fan Centrifugal Flow		Fan Axial Flow	
Roll Type Filter		Filter	
Humidifiers		Coils (H-heating C-cooling)	
Refrigeration unit (centrifugal compressor)		Refrigeration unit (positive displacement compressor)	

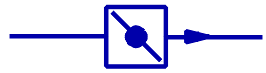
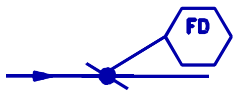
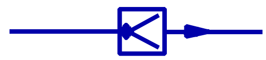
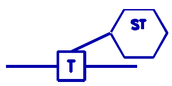
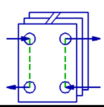
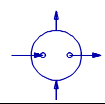
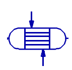
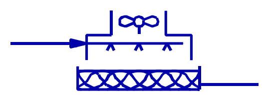
Figure 57 VENTILATION DAMPER SYMBOLS			
Butterfly Damper		Parallel Blade Damper	
Opposed Blade Damper		Bubble Tight Damper	
Fire Damper		Tornado Damper	
Backdraft Damper			

Figure 58 MISCELLANEOUS STEAM LINE SYMBOLS			
Steam Trap			
Plate type heat exchanger		Shell and tube heat exchanger	
Cooler or condenser		Cooling tower	

Systems are monitored for indication, control, or both. To create a usable signal, a device is usually inserted into the system to monitor the condition. Figure 59 shows the symbols used for various **sensing devices** and **detectors**.

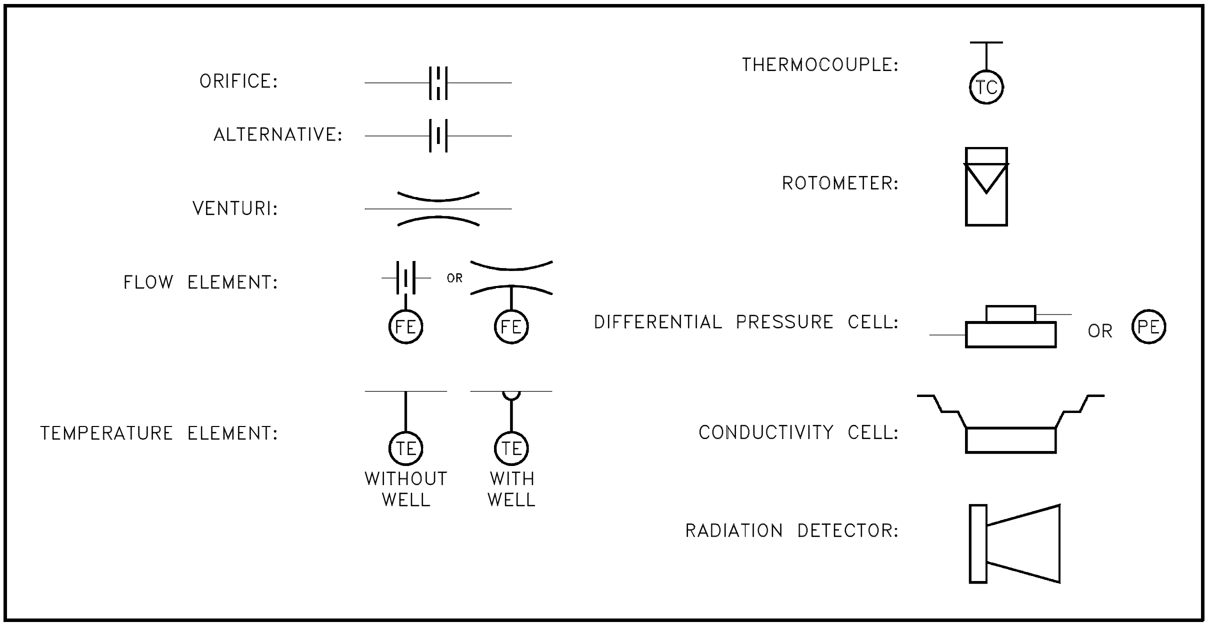


Figure 59 Detector and Sensing Device Symbols

Indicators and **recorders** are instruments used to convert the signal generated by an instrument loop into a readable form. Figure 60 shows examples of the symbols used for indicators and recorders.

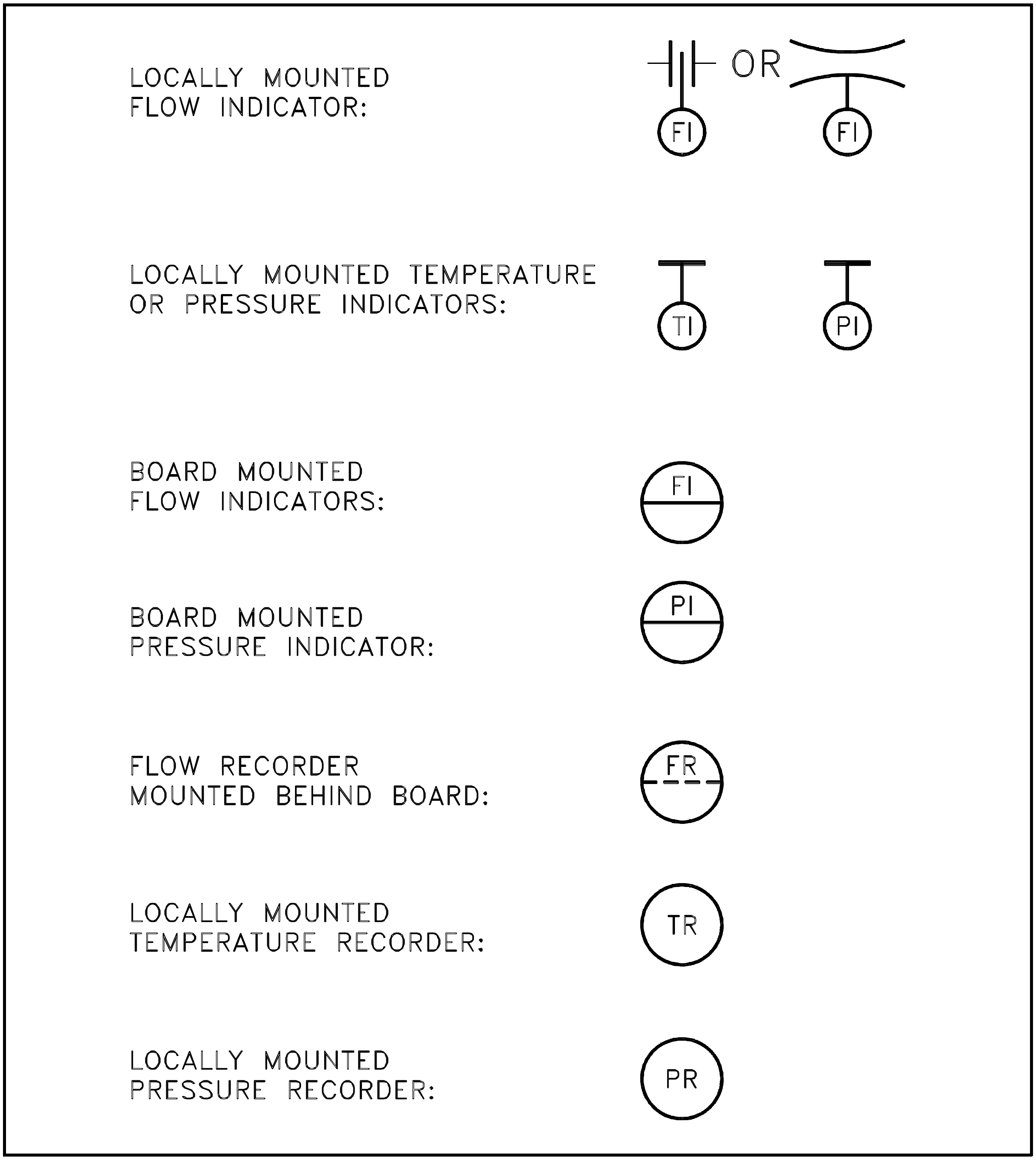


Figure 60 Indicators and Recorders

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **1.22-W.1.a**, **1.23-X.1.a**, and **1.24-Y.1.a** refer to:
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Introduction to Print Reading.

b. For Supporting Knowledge and Skills **1.22-W.1.b**, **1.23-X.1.b**, and **1.24-Y.1.b** refer to
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Piping and Instrumentation Diagrams.

c. For Supporting Knowledge and Skills **1.22-W.1.c**, **1.23-X.1.d**, and **1.24-Y.1.d** refer to
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Piping and Instrumentation Diagrams.

d. For Supporting Knowledge and Skills **1.22-W.1.d**, **1.23-X.1.e**, and **1.24-Y.1.e** refer to
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Piping and Instrumentation Diagrams.

e. For Supporting Knowledge and Skills **1.22-W.1.e** refer to
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Piping and Instrumentation Diagrams.

f. For Supporting Knowledge and Skills **1.22-W.1.f** refer to

g. For Supporting Knowledge and Skills **1.23-X.1.c**, and **1.24-Y.1.c** refer to
   - Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100) Chapter Piping and Instrumentation Diagrams.

h. For Supporting Knowledge and Skills **1.23-X.1.f**, and **1.24-Y.1.f** refer to
   - American National Standards Institute (1979). Graphic Symbols for Fluid Power Diagrams (ANSI Y32.10). New York, NY: American National Standards Institute
   - Anders, James E. Sr. (1983). Industrial Hydraulics Troubleshooting. New York, NY:

McGraw-Hill Book Company. ISBN 0-07-001592-9.

i. For Supporting Knowledge and Skills **1.23-X.1.g** refer to:
   - DOE-STD-1073-93-Pt.1 (1993). Guide for Operational Configuration Management Program

4. Practice Exercise

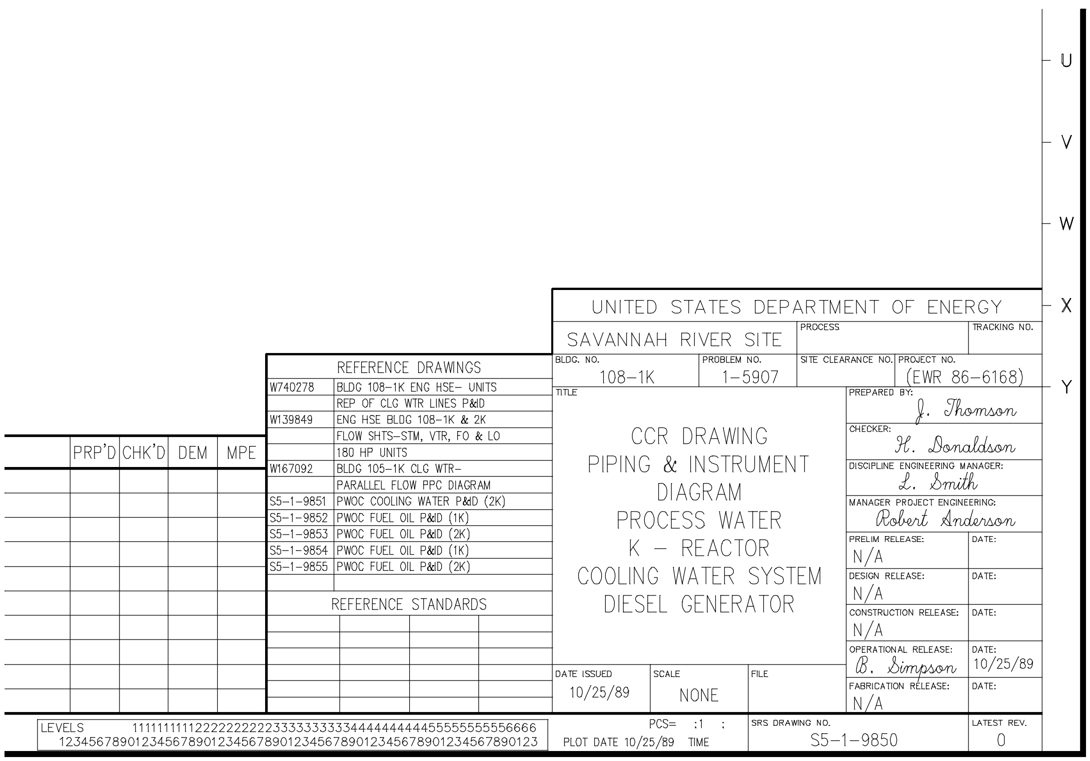
   a. Refer to the engineering print below, read and determine the following information: (K&S 1.22-W.1.a.) (K&S 1.23-X.1.a.) (K&S 1.24-Y.1.a.)

   Drawing title -

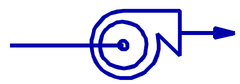
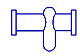
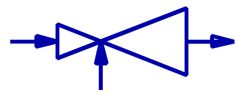
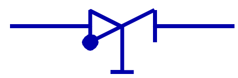
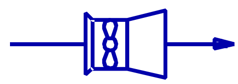
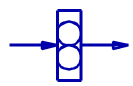
   Drawing number -

   Revision -

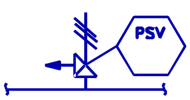
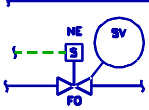
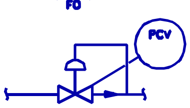
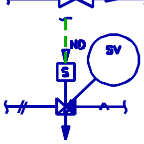
   Reference Drawings -



b. Match the description in column A with the P&ID symbol in column B. The column B answers **MAY** be used **MORE** than one time. Ignore any response in column B not identified in column A. (K&S 1.22-W.1.b.) (K&S 1.23-X.1.b.) (K&S 1.24-Y.1.b.)

Column A	Column B
__ 1. Compressor	a. 
__ 2. Eductor	b. 
__ 3. Positive displacement pump	c. 
__ 4. Centrifugal fan	d. 
	e. 
	f. 

c. Match the description in column A with the P&ID symbol in column B. The column B answers **MAY** be used **MORE** than one time. Ignore any response in column B not identified in column A. (K&S 1.22-W.1.b.) (K&S 1.23-X.1.b.) (K&S 1.24-Y.1.b.)

Column A	Column B
__ 1. 	a. Solenoid operated gate valve
	b. Diaphragm operated globe valve
__ 2. 	c. Pressure control (reducing) valve
__ 3. 	d. Relief valve
	e. Safety valve
__ 4. 	f. 3-way pilot valve

d. Match the description in column A with the P&ID valve symbol in column B. The column B answers **MAY** be used **MORE** than one time. Ignore any response in column B not identified in column A. (K&S 1.22-W.1.c.) (K&S 1.23-X.1.d.) (K&S 1.24-Y.1.d.)

Column A

__ 1. Open Gate valve

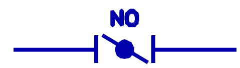
__ 2. Globe valve

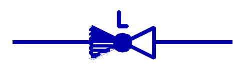
__ 3. Locked Closed Gate valve

__ 4. Butterfly valve

Column B

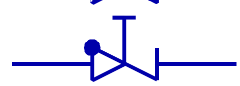
a. 

b. 

c. 

d. 

e. 

f. 

e. Describe the symbols and lettering used on engineering P&IDs to denote the location and function of the following instruments, indicators, and controllers. (K&S 1.23-X.1.c.) (K&S 1.24-Y.1.c.)

1) Locally mounted temperature indicator

2) Board mounted flow controller

3) Locally mounted pressure indicator transmitter

5. Practice Exercise Answers

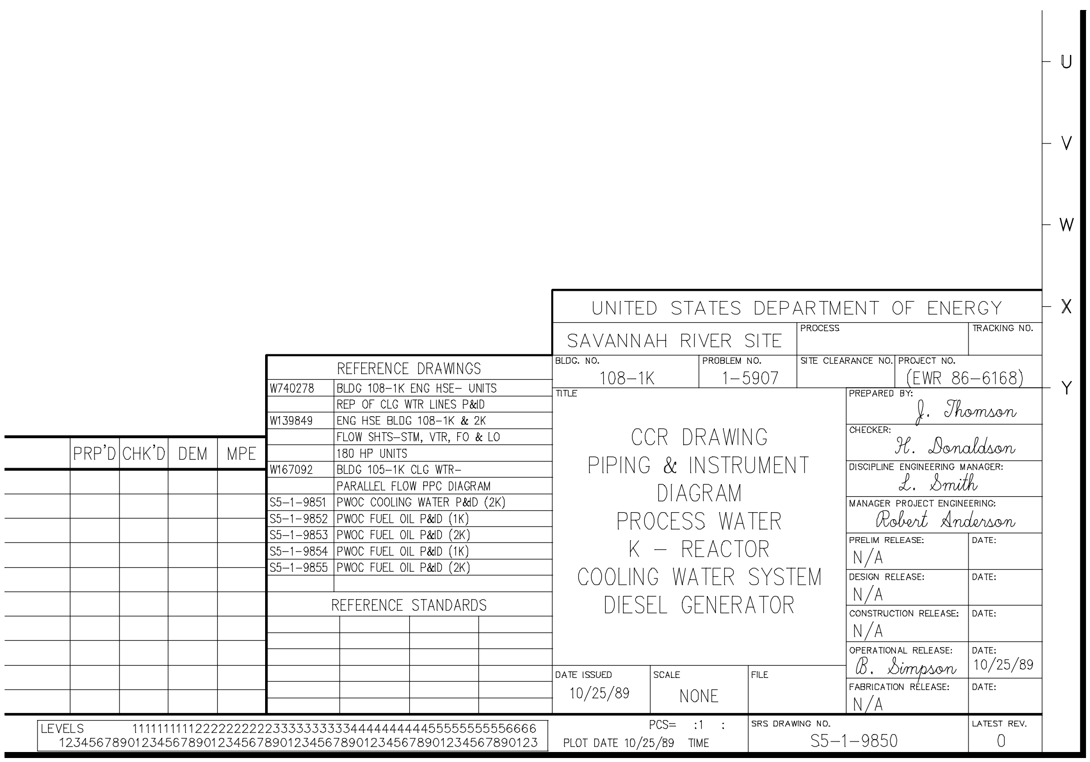
   a. Refer to the engineering print below, read and determine the following information: (K&S 1.22-W.1.a.) (K&S 1.23-X.1.a.) (K&S 1.24-Y.1.a.)

   Drawing title - CCR Drawing P&ID Process Water K- Reactor Cooling Water System Diesel Generator

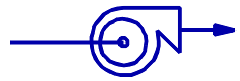
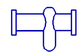
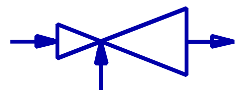
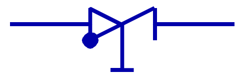
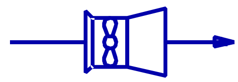
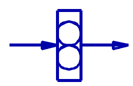
   Drawing number - S5-1-9850

   Revision - 0

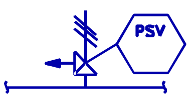
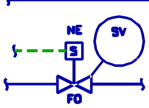
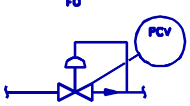
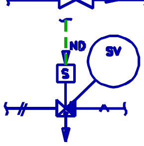
   Reference Drawings - w7400278, W139849, W167092, S5-1-9851, S5-1-9852, S5-1-9853, S5-1-9854, S5-1-9855



b. Match the description in column A with the P&ID symbol in column B. The column B answers **MAY** be used **MORE** than one time. Ignore any response in column B not identified in column A. (K&S 1.22-W.1.b.) (K&S 1.23-X.1.b.) (K&S 1.24-Y.1.b.)

Column A	Column B
_f_ 1. Compressor	a. 
_c_ 2. Eductor	b. 
_f_ 3. Positive displacement pump	c. 
_a_ 4. Centrifugal fan	d. 
	e. 
	f. 

c. Match the description in column A with the P&ID symbol in column B. The column B answers **MAY** be used **MORE** than one time. Ignore any response in column B not identified in column A. (K&S 1.22-W.1.b.) (K&S 1.23-X.1.b.) (K&S 1.24-Y.1.b.)

Column A	Column B
_e_ 1. 	a. Solenoid operated gate valve
_a_ 2. 	b. Diaphragm operated globe valve
_c_ 3. 	c. Pressure control (reducing) valve
_f_ 4. 	d. Relief valve
	e. Safety valve
	f. 3-way pilot valve

d. Match the description in column A with the P&ID valve symbol in column B. The column B answers **MAY** be used **MORE** than one time. Ignore any response in column B not identified in column A. (K&S 1.22-W.1.c.) (K&S 1.23-X.1.d.) (K&S 1.24-Y.1.d.)

Column A

_a_ 1. Open Gate valve

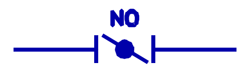
_c_ 2. Globe valve

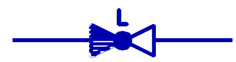
_e_ 3. Locked Closed Gate valve

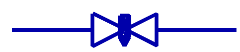
_b_ 4. Butterfly valve

Column B

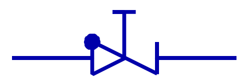
a. 

b. 

c. 

d. 

e. 

f. 

e. Describe the symbols and lettering used on engineering P&IDs to denote the location and function of the following instruments, indicators, and controllers. (K&S 1.23-X.1.c.) (K&S 1.24-Y.1.c.)

1) Locally mounted temperature indicator

"TI" inside circle

2) Board mounted flow controller

"FC" inside circle with horizontal dashed line across the diameter

3) Locally mounted pressure indicator transmitter

"PIT" inside circle

Z. **Competency 1.25**

Mechanical systems (FAC# 2.1) personnel shall demonstrate a working level knowledge of the mechanical systems related sections and/or requirements of Department of Energy (DOE) Order 6430.1A, General Design Criteria, Division 1, General Requirements, and Division 15, Mechanical.

1. Supporting Knowledge and Skills

   a. Discuss the use of Division 1, General Requirements, in the identification of design requirements for mechanical systems in Department facilities.

   b. Describe the purpose, scope, and application of the requirements detailed in DOE Order 6430.1A, General Design Criteria, Division 15.

   c. Discuss what constitutes acceptable contractor work performance with the of DOE Order 6430.1A, General Design Criteria.

   d. Discuss the relationship between industry standards and Division 15, Mechanical, of DOE Order 6430.1A, General Design Criteria.

   e. Discuss the relationship between the American National Standards Institute (ANSI) standards and Division 15 of DOE Order 6430.1A, General Design Criteria.

   f. Discuss what constitutes a safety class item as defined in DOE 6430.1A, General Design Criteria.

   g. Discuss the application of single failure criteria to mechanical systems.

   h. Discuss the environmental qualification criteria for mechanical system equipment.

   i. Discuss the requirements for testing capability for mechanical systems as specified in DOE 6430.1A, General Design Criteria.

   j. Discuss the criteria for generic human factors engineering considerations in DOE 6430.1A, General Design Criteria, as they apply to mechanical systems.

   k. Using a design package for a mechanical system, civil, or structural application, determine the general design criteria requirements for the mechanical system and components.

AA. Competency 1.26

Mechanical systems (FAC# 4.1) personnel shall demonstrate the ability to determine the adequacy of local compliance with the mechanical systems related sections and/or requirements of Divisions 1 and 15 of Department of Energy (DOE) Order 6430.1A, General Design Criteria.

1. Supporting Knowledge and Skills

   a. Using the General Design Criteria identify the requirements for mechanical systems personnel in Division 15 for the following systems as they apply to defense nuclear facilities:

      - Mechanical insulation
      - Service piping
      - Heating, ventilation, and air-conditioning systems
      - Refrigeration
      - Cryogenic systems

   b. Using project-specific data for each of the above systems, apply the requirements contained in Division 15 to verify that requirements have been met.

   c. Using Division 15 as a reference, prepare and implement a plan for performing a surveillance of contractor mechanical systems activities for mechanical systems personnel. Include any factors that may influence the level of coverage in the plan.

   d. Determine contractor compliance with the applicable provisions of Division 15 of the General Design Criteria.

   e. Using Divisions 1 and 15 of the General Design Criteria, prepare an action plan which: adequately outlines interviews and observations to be conducted; and, details the documents to review during an evaluation of contractor compliance against the requirements of the Order.

   f. Using an appropriate level of coverage, conduct an evaluation of contractor compliance with the requirements of Division 15 of the General Design Criteria. During this evaluation, demonstrate the ability to properly conduct interviews, observations, and document reviews.

   g. Using data from an evaluation, analyze the results of the evaluation to determine contractor compliance or noncompliance with the requirements.

h. Using the results from an analysis of contractor compliance or noncompliance, document and communicate the results to contractor and Department line management.

i. Using a system's technical manuals and design drawings, inspect the system for compliance with Division 15 of the General Design Criteria.

j. Using system specifications for an air-emission control system, evaluate whether emissions will be reduced to specified levels.

k. Using the design for a carbon-dioxide fire-suppression system and the volume of the space that it would protect, determine whether a fire within that space would be controlled.

2. Self-Study Information

Competency 1.25 and 1.26 address the knowledge of the principles associated with the mechanical system related sections and/or requirements of Department of Energy (DOE) Order 6430.1A, General Design Criteria, Division 1, General Requirements, and Division 15, Mechanical. Competency 1.25 at a working level and Competency 1.26 at a demonstrate the ability of knowledge.

The supporting material for the Self-Study includes the following document:

- Department of Energy (DOE) Order 6430.1A, General Design Criteria
- DOE 4700.1, Chapter V
- DOE 5440.1C National Environmental Policy Act
- DOE 5450.4
- DOE 5480.1B Environment, Safety, and Health Program for Department of Energy Operations
- EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room
- IEEE 379, Standard Application of the Single Failure Criterion to Nuclear Power Generating Station Class 1E Systems
- UCRL 15673, Human Factors Design Guidelines for Maintainability of DOE Nuclear Facilities (available from NTIS)
- Meister, D. and G. Rabideau, (1965). Human Factors Evaluation in System Development. New York, NY: John Wiley & Sons.

Purpose, scope, and application of the General Design Criteria, Division 15 -

The Order provides guidance for the mandatory, minimally acceptable requirements for DOE facility design criteria. The document provides general design criteria for use in the acquisition of DOE facilities. The document lists regulatory requirements cited throughout the document.

This document also provides guidance for design includes requirements for facility structures and systems (fire suppression, explosive facilities, telecommunications, radioactive processing and storage facilities, plumbing, ventilation, cooling systems, and storage facilities).

Acceptable contractor work performance -

Prior to final acceptance of a completed contract, the construction contractor shall provide the Contracting Officer various data needed for the successful operation of the facility and material assuring compliance with the construction documents. Contract documents shall ensure that the contractor is responsible for delivering these items.

The document provide a listing of items (DOE Order 6430.1A section 0170-1) that should be submitted and reviewed prior to contract close out. The list includes but is not limited to: project documentation; final survey locations and physical features including; field test reports; and manufacturers' and supplier's data including contractor-designed items.

The Contracting Officer shall initiate contract closeout procedures (DOE Order 6430.1A section 0170-2). Construction completion and closeout procedures shall be as required by DOE 4700.1.

Safety class item -

Systems, components, and structures whose failure could adversely affect the environment or the safety and health of the public. The following are characteristics of safety class items (DOE Order 6430.1A section 1300-3.2):

- Those whose failure would produce radiological exposures in excess of the guidelines at the site boundary or nearest public access.
- Those required to maintain operating parameters within safety limits during normal operations and anticipated operational occurrences.
- Those required for nuclear criticality safety.
- Those required to monitor the release of radioactivity during a Design Basis Accident (DBA).
- Those required to achieve and maintain the facility in a safe shutdown condition.
- Those that control any safety item discussed above.

The document classifies and discusses the three level of safety class items (SC-1, SC-2, and SC-3).

Safety class items are required to be operable and perform the required safety functions under DBA conditions (DOE Order 6430.1A section 1300-3.4.2). The equipment must be able to perform a specified period of time. The limiting condition is based on the most severe postulated accident. Conditions to be considered include temperature, pressure, humidity, radiological and chemical environment.

Headquarters-level review and approval shall be required for the deviations proposed for safety-class items (DOE Order 6430.1A section 1300-3.2 and DOE 5481.1B) when such deviation will or may constitute an adverse impact on environmental protection, safety or health or other DOE design policies or objectives.

Safety class structures (DOE Order 6430.1A section 0111-99.0.1) are sometimes required in special facilities for the following reasons:

- For nuclear criticality safety
- To prevent or mitigate the release of quantities and concentrations of radioactive materials that have the potential to exceed the release guidelines (DOE Order 6430.1A section 1300-1.4)
- To achieve and maintain the facility in a safe shutdown condition

Safety Class Criteria (DOE Order 6430.1A section 1300-3) addresses the safety classification and required criteria for safety class structures.

Safety class items required to function during or following severe natural phenomena shall not be prevented from performing their required safety functions by the failure of components, systems, or structures that are not designed to the severe natural phenomena criteria.

The document specifically provides guidance for several mechanical systems that are required to be safety class. General Cooling System Criteria (DOE Order 6430.1A section 1540-99.0.1); General Ventilation and Off-Gas Criteria (DOE Order 6430.1A section 1550-99.0.1); and Confinement Ventilation Systems (DOE Order 6430.1A section 1550-99.0.2).

Single failure criteria -

An occurrence that results in the loss of capability of a component to perform its intended safety Function(s). Multiple failures, resulting from a single occurrence are considered to be a single failure. Systems are considered to be designed against an assumed single failure if neither (1) a single failure of any active component nor, (2) a single failure of any passive component results in the loss of the systems capability to perform its safety function(s).

The document references IEEE 379, Standard Application of the Single Failure Criterion to Nuclear Power Generating Station Class 1E Systems for additional information.

Environmental qualification criteria -

Safety class items are required to be operable and perform the required safety functions under DBA conditions (DOE Order 6430.1A section 1300-3.4.2). The equipment must be able to perform a specified period of time. The limiting condition is based on the most severe postulated accident. Conditions to be considered include temperature, pressure, humidity, radiological and chemical environment.

This document also provides guidance for control and regulating the effect DOE facilities and systems have on the environment. Environmental regulation includes requirements for facility structures and systems (ventilation, cooling systems, radioactivity releases, and disposal facilities).

The construction of all DOE facilities (DOE Order 6430.1A section 0110-7) shall comply with the environmental protection and pollution control portions of the following:

- DOE 5440.1C National Environmental Policy Act
- DOE 5450.4
- DOE 4700.1, Chapter V
- DOE 5480.1B Environment, Safety, and Health Program for Department of Energy Operations

Testing capability -

Safety class items are required to designed to include the ability to test the monitoring, surveillance, and alarm system (DOE Order 6430.1A section 1300-3.6). The safety class items is required to be capable of being tested under simulated emergency conditions.

This document also provides guidance for testing requirements of components and systems installed in DOE facilities. Some testing is performed for acceptance criteria while other testing is performed to ensure operability of equipment during inservice usage. Testing includes requirements for facility structures and systems (fire suppression, ventilation, cooling systems, and storage facilities).

Generic human factors engineering

This document provide guidance for the incorporation of human factors engineering into the design, operation, and maintenance of DOE facilities (DOE Order 6430.1A section 1300-12). The guidance addresses work environment and man-machine interfaces. General guidance is provided for incorporating human factors engineering in system design, displays, controls, alarms, labelling, and communication. The criteria includes such matter as ventilation; lighting; noise control; work space layout; and equipment design and layout.

Human factors engineering is used to reduce human error, increase productivity, lower costs, better product quality, decrease equipment and property damage; improve program schedules;personal job satisfaction; and improvements in safe operation and maintenance of DOE facilities.

The document cites several reference for additional information on human factors engineering:

- EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room
- UCRL 15673, Human Factors Design Guidelines for Maintainability of DOE Nuclear Facilities (available from NTIS)
- D. Meister and G. Rabideau, Human Factors Evaluation in System Development, John Wiley & Sons, New York, 1965

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **1.25-Z.1.a.** through **1.26-AA.1.k.** refer to Department of Energy (DOE) Order 6430.1A, General Design Criteria

4. Practice Exercise

a. The Order provides guidance for the mandatory, minimally acceptable requirements for DOE facility design criteria. The document provides general design criteria for use in the acquisition of DOE facilities. List four systems addressed in the Order. (K&S 1.25-Z.1.b.)

   1.

   2.

   3.

   4.

b. Who is responsible to ensure that acceptable contractor work performance is accomplished? (K&S 1.25-Z.1.c.)

c. List the six (6) characteristics that constitutes a safety class item as defined in DOE 6430.1A, General Design Criteria. (K&S 1.25-Z.1.f.)

   1.

   2.

   3.

   4.

   5.

   6.

d. What approval is required for deviations proposed for a safety class item as defined in DOE 6430.1A, General Design Criteria? Which section of the order addresses this. (K&S 1.25-Z.1.f.)

e. What constitutes a single failure criteria to mechanical systems as defined in DOE 6430.1A, General Design Criteria? (K&S 1.25-Z.1.g.)

f. Discuss the environmental qualification criteria for mechanical system equipment. (K&S 1.25-Z.1.h.)

g. Discuss the requirements for testing capability for mechanical systems as specified in DOE 6430.1A, General Design Criteria. (K&S 1.25-Z.1.i.)

h. What is the purpose of generic human factors engineering considerations in DOE 6430.1A, General Design Criteria, as they apply to mechanical systems?

5. Practice Exercise Answers

a. The Order provides guidance for the mandatory, minimally acceptable requirements for DOE facility design criteria. The document provides general design criteria for use in the acquisition of DOE facilities. List four systems addressed in the Order. (K&S 1.25-Z.1.b.)

1. Fire suppression
2. Explosive facilities
3. Telecommunications
4. Radioactive processing and storage facilities
   Plumbing
   Ventilation
   Cooling systems
   Storage facilities

b. Who is responsible to ensure that acceptable contractor work performance is accomplished? (K&S 1.25-Z.1.c.)

Prior to final acceptance of a completed contract, the construction contractor shall provide the Contracting Officer various data needed for the successful operation of the facility and material assuring compliance with the construction documents. Contract documents shall ensure that the contractor is responsible for delivering these items. The Contracting Officer shall initiate contract closeout procedures (DOE Order 6430.1A section 0170-2). Construction completion and closeout procedures shall be as required by DOE 4700.1.

c. List the six (6) characteristics that constitutes a safety class item as defined in DOE 6430.1A, General Design Criteria. (K&S 1.25-Z.1.f.)

1. Those whose failure would produce radiological exposures in excess of the guidelines at the site boundary or nearest public access.
2. Those required to maintain operating parameters within safety limits during normal operations and anticipated operational occurrences.
3. Those required for nuclear criticality safety.
4. Those required to monitor the release of radioactivity during a Design Basis Accident (DBA).
5. Those required to achieve and maintain the facility in a safe shutdown condition.
6. Those that control any safety item discussed above.

d. What approval is required for deviations proposed for a safety class item as defined in DOE 6430.1A, General Design Criteria? Which section of the order addresses this. (K&S 1.25-Z.1.f.)

   Headquarters-level review and approval shall be required for the safety-class items (DOE Order 6430.1A section 1300-3.2 and DOE 5481.1B) when such deviation will or may constitute an adverse impact on environmental protection, safety or health or other DOE design policies or objectives.

e. What constitutes a single failure criteria to mechanical systems as defined in DOE 6430.1A, General Design Criteria? (K&S 1.25-Z.1.g.)

   An occurrence that results in the loss of capability of a component to perform its intended safety Function(s). Multiple failures, resulting from a single occurrence are considered to be a single failure. Systems are considered to be designed against an assumed single failure if neither:

   (1) a single failure of any active component

   nor,

   (2) a single failure of any passive component results in the loss of the systems capability to perform its safety function(s).

f. Discuss the environmental qualification criteria for mechanical system equipment. (K&S 1.25-Z.1.h.)

   Safety class items are required to be operable and perform the required safety functions under DBA conditions (DOE Order 6430.1A section 1300-3.4.2). The equipment must be able to perform a specified period of time. The limiting condition is based on the most severe postulated accident. Conditions to be considered include temperature, pressure, humidity, radiological and chemical environment.

g. Discuss the requirements for testing capability for mechanical systems as specified in DOE 6430.1A, General Design Criteria. (K&S 1.25-Z.1.i.)

   Safety class items are required to designed to include the ability to test the monitoring, surveillance, and alarm system (DOE Order 6430.1A section 1300-3.6). The safety class items is required to be capable of being tested under simulated emergency conditions.

h. What is the purpose of generic human factors engineering considerations in DOE 6430.1A, General Design Criteria, as they apply to mechanical systems?

Human factors engineering is used to reduce human error, increase productivity, lower costs, better product quality, decrease equipment and property damage; improve program schedules;personal job satisfaction; and improvements in safe operation and maintenance of DOE facilities.

AB. **Competency 1.27**

Mechanical systems (FAC# 2.10, 2.11, 2.12, 2.13, 2.14, 2.15, 2.16, & 2.17) personnel shall demonstrate a familiarity level knowledge of the codes and standards of:

- **American Institute of Steel Construction (AISC)**
- **American National Standards Institute (ANSI)**
- **American Nuclear Society (ANS)**
- **American Petroleum Institute (API)**
- **American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)**
- **American Society of Mechanical Engineers (ASME)**
- **American Society of Testing and Materials (ASTM)**
- **Society of Automotive Engineers (SAE)**

1. Supporting Knowledge and Skills

a. Discuss the following American Institute of Steel Construction (AISC) documents and their relationship to the design and construction of mechanical systems:

- AISC M 011 (MO16-89), Manual of Steel Construction Allowable Stress Design
- AISC N 690 (S327-84), Nuclear Facility - Steel Safety - related Structures for Design, Fabrication, and Erection
- AISC S 326 (S328-86), Specifications for Structural Steel Building Load and Resistance Factor Design

b. Discuss the following American National Standards Institute (ANSI) documents and their relationship to the design, construction, and operation of mechanical systems:

- ANSI N 8.3, Criticality Accident Alarm System
- ANSI Z 358.1, Emergency Eyewash and Shower Equipment

c. Discuss the following American Nuclear Society (ANS) documents and their relationship to the design, construction, and operation of mechanical systems:

- ANS 8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors
- ANS 8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials
- ANS 8.9, Nuclear Criticality Safety Criteria for Steel Pipe Intersections Containing Aqueous Solutions of Fissile Material
- ANS 15.1, Development of Technical Specifications for Research Reactors

- ANS 59.1, Nuclear Safety-Related Cooling Water Systems in Nuclear Power Plants
- ANS 59.3, Nuclear Safety Criteria for Control Air Systems
- ANS 59.51, Fuel Oil Systems for Emergency Diesel Generators

d. Discuss API 650, Welded Steel Tanks for Oil Storage, and its relation to the design, construction, and / or modification of oil storage systems.

e. Discuss the following American Society of Heating, Refrigeration, and Air Conditioning Engineers documents and their relationship to design, construction, and operations of HVAC systems:

- ASHRAE 15, Safety Code for Mechanical Refrigeration
- ASHRAE 51, Laboratory Methods for Testing Fans for Rating
- ASHRAE 62, Ventilation Requirements for Acceptable Indoor Air Quality
- ASHRAE 90, Energy Conservation in New Building Design
- ASHRAE 100, Energy Conservation in Existing Building Design

f. Discuss the following American Society of Mechanical Engineers (ASME) documents and their relationship to the design, construction, and / or modification of mechanical systems:

- ASME B31.1, Power Piping
- ASME B31.3, Chemical Plant and Petroleum Refinery Piping
- ASME N510, Testing of Nuclear Air Cleaning Systems
- ASME NQA-1, Quality Assurance Requirements for Nuclear Facilities Application (contains revisions from ASME NQA-2, Quality Assurance Program Requirements for Nuclear Facilities Application)
- ASME B 16, Fitting, Flanges, and Valves
- ASME BPVC, Boiler and Pressure Vessel Code

g. Discuss the following American Society of Testing and Materials documents and their relation to design, construction, and / or modifications to mechanical systems:

- ASTM A 312, Standard Specification for Seamless and Austenitic Stainless Steel Pipe
- ASTM G 46, Standard Practice for Examination and Evaluation of Pitting Corrosion

h. Discuss the following Society of Automotive Engineers documents and their relationship to design, construction, and operations of mechanical systems:

- SAE J30, Fuel and Oil Hoses
- SAE J827, Cast Steel Shot
- SAE J1053, Steel Stamped Nuts of One Pitch Thread Design
- SAE J1900, Seals-Bond Test Fixture and Procedure
- SAE J1945, Cross-Tooth Companion Flanges, Type T
- SAE J2016, Chemical Stress Resistance of Polymers
- SAE J2045, Tube/Hose Assemblies
- SAE J2096, Categorization of Low-Carbon Automotive Sheet Steel
- SAE HS 2100, Numbering System for Standard Drills, Standard Taps and Reamers

i. Describe the hierarchy of the mechanical rules, codes, Orders, and standards at defense nuclear facilities and explain where the above standards and codes fall within that hierarchy.

j. Discuss the applicability of the above standards and codes documents to defense nuclear facilities.

2. Self-Study Information

Competency 1.27 addresses the familiarity level knowledge of the codes and standards of the following organizations:

- American Institute of Steel Construction (AISC)
- American National Standards Institute (ANSI)
- American Nuclear Society (ANS)
- American Petroleum Institute (API)
- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
- American Society of Mechanical Engineers (ASME)
- American Society of Testing and Materials (ASTM)
- Society of Automotive Engineers (SAE)

The supporting material for the Self-Study Activities include the following documents:

- AISC M 011 (MO16-89), Manual of Steel Construction Allowable Stress Design
- AISC N 690 (S327-84), Nuclear Facility - Steel Safety - related Structures for Design, Fabrication, and Erection

- AISC S 326 (S328-86), Specifications for Structural Steel Building Load and Resistance Factor Design
- ANSI N 8.3, Criticality Accident Alarm System
- ANSI Z 358.1, Emergency Eyewash and Shower Equipment
- ANS 8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors
- ANS 8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials
- ANS 8.9, Nuclear Criticality Safety Criteria for Steel Pipe Intersections Containing Aqueous Solutions of Fissile Material
- ANS 15.1, Development of Technical Specifications for Research Reactors
- ANS 59.1, Nuclear Safety-Related Cooling Water Systems in Nuclear Power Plants
- ANS 59.3, Nuclear Safety Criteria for Control Air Systems
- ANS 59.51, Fuel Oil Systems for Emergency Diesel Generators
- API 650, Welded Steel Tanks for Oil Storage
- ASHRAE 15, Safety Code for Mechanical Refrigeration
- ASHRAE 51, Laboratory Methods for Testing Fans for Rating
- ASHRAE 62, Ventilation Requirements for Acceptable Indoor Air Quality
- ASHRAE 90, Energy Conservation in New Building Design
- ASHRAE 100, Energy Conservation in Existing Building Design
- ASME B31.1, Power Piping
- ASME B31.3, Chemical Plant and Petroleum Refinery Piping
- ASME N510, Testing of Nuclear Air Cleaning Systems
- ASME NQA-1, Quality Assurance Requirements for Nuclear Facilities Application (contains revisions from ASME NQA-2, Quality Assurance Program Requirements for Nuclear Facilities Application)
- ASME B 16, Fitting, Flanges, and Valves
- ASME BPVC, Boiler and Pressure Vessel Code
- ASTM A 312, Standard Specification for Seamless and Austenitic Stainless Steel Pipe
- ASTM G 46, Standard Practice for Examination and Evaluation of Pitting Corrosion
- SAE J30, Fuel and Oil Hoses
- SAE J827, Cast Steel Shot
- SAE J1053, Steel Stamped Nuts of One Pitch Thread Design
- SAE J1900, Seals-Bond Test Fixture and Procedure
- SAE J1945, Cross-Tooth Companion Flanges, Type T
- SAE J2016, Chemical Stress Resistance of Polymers
- SAE J2045, Tube/Hose Assemblies
- SAE J2096, Categorization of Low-Carbon Automotive Sheet Steel
- SAE HS 2100, Numbering System for Standard Drills, Standard Taps and Reamers

American Institute of Steel Construction (AISC) Documents

AISC M 011 (MO16-89), Manual of Steel Construction Allowable Stress Design

This document provides guidance on the selection and use of steel materials in construction. The manual includes specific information on structural steel dimensions and properties; beam and girder design; column design; connections; and specifications and codes.

AISC N 690 (S327-84), Nuclear Facility - Steel Safety - Related Structures for Design, Fabrication, and Erection

This standard addresses the design, fabrication, and erection of structural steel for steel safety related structures for nuclear facilities. The specification in this manual also apply to composite structures consisting of structural steel and concrete.

AISC S 326 (S328-86), Specifications for Structural Steel Building Load and Resistance Factor Design

This document provides design criteria for routine use in the design of steel frame buildings. Information includes: materials for use in steel frame buildings; loads and load combinations; design basis; reference codes and standards; and applicable design documents.

American National Standards Institute (ANSI) Documents

ANSI N 8.3, Criticality Accident Alarm System

This standard is designed to address the criticality Accident alarm systems to be used in facilities and at locations where the possibility of an accidental criticality may occur. This is necessary because, while the probability of a criticality is very low, the risk cannot be eliminated. The standard provides information on system detectors, alarm dependability, and information on the criteria to be considered in system design to include Reliability, Vulnerability, response times, detector criteria, sensitivity, spacing, testing, records and employee familiarization.

ANSI Z358.1, Emergency Eyewash and Shower Equipment

This standard establishes the minimum performance requirements for eyewash and shower equipment for the emergency treatment of the eyes or body of a person who has been exposed to injurious materials. The equipment include in this standard include the following emergency equipment:

- Emergency Showers
- Eyewash Equipment
- Eye/face wash equipment
- Hand-held drench hoses
- Combination shower and eyewash or eye/face wash stations

This standard is intended to provide minimum requirements for equipment performance, installation, test procedures, and maintenance and training in order to assure workers of a minimum level of first aid.

American Nuclear Society (ANS) Documents

ANS 8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors

This standard provides guidance for the prevention of criticality accidents in the handling, storing, processing and transportation of fissionable material outside of nuclear reactors. It presents generalized basic criteria and limits for some single fissionable units of simple shape containing U-238, U-235, or Pu 239.

ANS 8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials

This guide provides general storage criteria for fissile materials. It contains information for parameters, limits and conditions for the storage of the materials to include storage configurations and safe storage arrays. This guide also supplies administrative and technical practices for nuclear criticality.

ANS 8.9, Nuclear Criticality Safety Criteria for Steel Pipe Intersections Containing Aqueous Solutions of Fissile Material

This standard provides criteria and data based on criticality experiments and validated calculations which are generally applicable to homogeneous aqueous solutions of fissile material. The standard provides specific information on fissile solutions containing uranium highly enriched in the U-235 or U-233 isotope, plutonium and uranium solutions having a U-235 content not exceeding 5 wt% of the total uranium. The standard is applicable to the storage, transfer and processing of homogeneous aqueous solutions in intersecting schedule 10, or heavier steel pipes.

ANS 15.1, Development of Technical Specifications for Research Reactors

This standard identifies and establishes the content of technical specifications for research reactors. Areas addressed are:

- Definitions
- Safety Limits
- Limiting Safety System Settings
- Limiting Conditions of Operations
- Surveillance Requirements
- Design Features
- Administrative Controls

Sufficient detail is incorporated into this standard so that applicable specifications can be derive or extracted.

ANS 59.1, Nuclear Safety-Related Cooling Water Systems for Light Water Reactors

This standard presents the requirements for the nuclear safety related cooling water systems for light water reactors. It establishes nuclear safety requirements in the areas of design, materials, fabrication, placement and testing of systems. Included in the standard are requirements for system descriptions, system performance criteria, design and quality assurance.

ANS 59.3, Nuclear Safety Criteria for Control Air Systems

This standard provide criteria for the control air system that furnishes compressed air to nuclear safety related components and other equipment that could affect any nuclear safety-related function in nuclear power plants. It includes nuclear safety design requirements and non-nuclear safety design recommendations for equipment, piping, instrumentation, and controls that constitute the control air system. It also includes nuclear safety design requirements and non-nuclear safety design recommendations to accommodate the testing and maintenance necessary to ensure adequate performance of the control air system.

ANS 59.51, Fuel Oil Systems for Emergency Diesel Generators

This standard provides functional, performance, and design requirements for the fuel oil system for diesel generators that provide emergency on-site power for light water reactor nuclear power plants. The standard defines those features of the fuel oil systems required to ensure an adequate fuel supply to emergency diesel generators and provides performance and design criteria to ensure sufficient fuel is available for supply to the emergency diesel generators under all plant conditions. This standard addresses all mechanical equipment associated with the fuel oil system.

American Petroleum Institute (API) Documents

American Petroleum Institute API 650, Welded Steel Tanks for Oil Storage

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Documents

ASHRAE 15, Safety Code for Mechanical Refrigeration

This standard is directed toward the safety of persons and property on or near the premises where refrigeration facilities are located. The standard includes information on the restrictions on refrigeration use, installation restrictions, design and construction of HVAC units and their operation and testing. While this document covers specifications for the fabrication of tight systems it does not include information of the effects of refrigerant emissions on the environment.

ASHRAE 51, Laboratory Methods for Testing Fans for Rating

This standard describe methods for the testing of fans, blowers, exhausters, compressors, or other moving devices when air is to be used as the test gas. The test methods described are for determining performance in terms of flow rate, pressure, power, air density, speed of rotation, and efficiency. This standard is not intended to cover units such as circulating fans such as ceiling or desk fans, compressors with interstage coolers, or positive displacement machines. Take note that this standard describes methods and does not define procedures.

ASHRAE 62, Ventilation Requirements for Acceptable Indoor Air Quality

This standard specifies minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects. The standard applies to all indoor or enclosed spaces that people may occupy. The standard includes appropriate procedures for the testing of ventilation rates and outdoor air quality.

ASHRAE 90, Energy Conservation in New Building Design

The purpose of this standard is to provide design requirements which will improve utilization of energy in new buildings and provide a means of determining the anticipated impact of energy utilization on the depletion of energy resources. The standard is directed toward the design of building envelopes with adequate thermal resistance and low air leakage, and the selection of mechanical, electrical, service water heating and illumination systems and equipment.

ASHRAE 100, Energy Conservation in Existing Building Design

ASHRAE 100 is a series of standard practices addressing energy conservation practices for the following:

- ASHRAE 100.2 - High-rise Residential Buildings
- ASHRAE 100.3 - Commercial Buildings
- ASHRAE 100.4 - Industrial Buildings
- ASHRAE 100.5 - Institutional Buildings
- ASHRAE 100.6 - Public Assembly Buildings

The standards establish methods for operating, maintaining, and monitoring buildings; implementing energy audits and determining reporting compliance in these areas.

American Society of Mechanical Engineers (ASME) Documents

ASME B31.1, Power Piping

This standard provides engineering requirements necessary for the safe design and construction of pressure piping. The standard provides these requirements in terms of basic design principles and formulas. The documents prohibits unsafe designs and practices and provides warnings where appropriate. The standard provide minimum requirements for the design, materials, fabrication, erection, test, and inspection of power and auxiliary service piping systems for electric generation stations, industrial , and institutional plants, central and district heating plants, and district heating systems.

This standard applies to all piping and components (including but not limited to steam, water, oil, gas, and air service) for external piping for power boilers. These boiler generate a steam or vapor pressure greater than 15 psig, and high temperature water pressures exceed 160 psig or temperatures exceed 250°F.

The standard includes:

1. References to acceptable material specifications.
2. Requirements for design of components and assemblies.
3. Requirements and data for evaluation and limitation of stresses, reactions, and movements.
4. Guidance for the selection and application of materials.
5. Requirements for the fabrication, assembly, and erection of piping.
6. Requirements for examination, inspection and testing of piping.

ASME B31.3, Chemical Plant and Petroleum Refinery Piping

This standard provides engineering requirements necessary for the safe design and construction of pressure piping. The standard provides these requirements in terms of basic design principles and formulas. The documents prohibits unsafe designs and practices and provides warnings where appropriate. This document provides the requirements for the design and construction, including fluid service requirements.

The standard includes:

1. References to acceptable material specifications.
2. Requirements for design of components and assemblies.
3. Requirements and data for evaluation and limitation of stresses, reactions, and movements.
4. Guidance for the selection and application of materials.
5. Requirements for the fabrication, assembly, and erection of piping.
6. Requirements for examination, inspection and testing of piping.

ASME N510, Testing of Nuclear Air Treatment Systems

This standard provides the requirements for field testing of Engineered Safety Feature and other high efficiency air-cleaning systems at nuclear facilities. The document provides a basis for the test program development and specifies requirements for reporting test results. The standard allows users to select appropriate tests relevant to the application. Minimum frequency of testing data is also provided.

ASME NQA-1, Quality Assurance Requirements for Nuclear Facilities Application
(Revision and consolidation of ASME NQA-1-1989 and ASME NQA-2-1989)

This standard provides the requirements for establishing and conducting quality assurance programs in nuclear facilities. The standard addresses siting, design, construction, operation, and decommissioning of nuclear facilities.

These activities include:
1. Attaining quality objectives.
2. Assuring establishment of a quality assurance program.
3. Verifying activities affecting quality are performed correctly.

These activities include siting, designing, purchasing, fabricating, handling, shipping, receiving, storing, cleaning, erecting, installing, inspecting, testing, operating, maintaining, repairing, refueling, modifying, and decommissioning.

ASME B 16, Fitting, Flanges, and Valves

ASME BPVC, Boiler and Pressure Vessel Code

American Society of Testing and Materials (ASTM) Documents

ASTM A 312, Standard Specification for Seamless and Austenitic Stainless Steel Pipe

This standard provides the following information related to design, construction, and/or modification to mechanical systems:

a. Ordering of material
b. Material and manufacturing
c. Chemical composition
d. Product analysis
e. Tensile requirements
f. Mechanical tests
g. Workmanship
h. Repairs

ASTM G 46, Standard Practice for Examination and Evaluation of Pitting Corrosion

This standard provides the following information related to design, construction, and/or modification to mechanical systems:

a. Identification and examination of pits
b. Nondestructive examination
c. Extent of pitting
d. Evaluation of pitting

Society of Automotive Engineers Documents

SAE J30, Fuel and Oil Hoses - Standard

This SAE standard covers fuel and oil hoses, coupled and uncoupled for use with gasoline, oil diesel fuel, lubricating oil, on the vapor present in either the fuel system of in the crankcase of internal combustion engines in mobile, stationary and marine applications. This standard includes information on the requirements for construction, qualification, testing, and inspections of fuel and oil hoses.

SAE J827, Cast Steel Shot- Recommended Practice

This SAE document is a recommended practice describing their chemical analysis, hardness, microstructure, and physical characteristics for cast steel shot to be used for shot peening or blast cleaning operations.

SAE J1053, Steel Stamped Nuts of One Pitch Thread Design - Standard

This SAE standard discusses the general, dimensional and performance specifications for those types, styles and sizes of stamped nuts of one pitch thread design recognized as SAE standard. The standard includes specific information on dimensional tolerance, thread embossments, materials, finish, and workmanship, as well as, testing procedures and performance requirements

SAE J1900, Seals-Bond Test Fixture and Procedure- Recommended Practice

This recommended practice describes a universal bond test fixture that can be mounted to a conventional tensile test machine. The test fixture is one that

a) does not require special tooling for each part size to be evaluated
b) provides quantitative information verses the qualitative evaluation of past testing fixtures thereby eliminating operator judgment and,
c) capable of producing repeatable results.

This SAE recommended practice includes a description of the fixture and procedures for its installation, adjustment, operation and subsequent evaluation of test measurement results.

SAE J1945, Cross-Tooth Companion Flanges, Type T- Standard

This standard is one in a series that describes the nominal dimensions and tolerances which affect the inter-changability between companion flanges and their mating parts. This specific standard addresses cross tooth companion flanges. Each of the SAE standards on companion flanges has an ISO counterpart.

SAE J2016, Chemical Stress Resistance of Polymers - Recommended Practice

This recommended practice provides a screening procedure for evaluating the susceptibility of plastics to environmental stress cracking by testing their reaction to pure solvents.

SAE J2045, Tube/Hose Assemblies - Standard

This SAE standard encompasses the minimum functional requirements for fuel tubing and nonmetallic and non rubber hose assemblies to be used in gasoline fuel injection systems. This standard includes test procedures to determine if tubing/hoses meet the standards requirements.

SAE J2096, Categorization of Low-Carbon Automotive Sheet Steel - Recommended Practice

This recommended practice establishes a nomenclature for categorizing low carbon automotive hot rolled sheet, cold rolled sheet, and zinc and zinc alloy coated sheet steel. Information available includes classifications, associated yield strengths, and product characteristics.

SAE HS 2100, Numbering System for Standard Drills, Standard Taps and Reamers

HS-2100 is a hands on manual made-up of several different documents including SAE J2122 - Numbering System for Standard Drills, SAE J2123 - Numbering System for Standard Taps, and SAE J2124 - Numbering System for Reamers. The manual provides a systematic method for identifying drills, standard taps and various types of hand, machine, and shell reamers used in industrial applications.

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **K&S 1.27-AB.1.a.** refer to the following American Institute of Steel Construction (AISC) documents:

- AISC M 011 (MO16-89), Manual of Steel Construction Allowable Stress Design
- AISC N 690 (S327-84), Nuclear Facility - Steel Safety - related Structures for Design, Fabrication, and Erection
- AISC S 326 (S328-86), Specifications for Structural Steel Building Load and Resistance Factor Design

b. For Supporting Knowledge and Skills **K&S 1.27-AB.1.b.** refer to the following American National Standards Institute (ANSI) documents:

- ANSI N 8.3, Criticality Accident Alarm System
- ANSI Z 358.1, Emergency Eyewash and Shower Equipment

c. For Supporting Knowledge and Skills **K&S 1.27-AB.1.c.** refer to the following American Nuclear Society (ANS) documents:

- ANS 8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors
- ANS 8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials
- ANS 8.9, Nuclear Criticality Safety Criteria for Steel Pipe Intersections Containing Aqueous Solutions of Fissile Material
- ANS 15.1, Development of Technical Specifications for Research Reactors
- ANS 59.1, Nuclear Safety-Related Cooling Water Systems in Nuclear Power Plants
- ANS 59.3, Nuclear Safety Criteria for Control Air Systems
- ANS 59.51, Fuel Oil Systems for Emergency Diesel Generators

d. For Supporting Knowledge and Skills **K&S 1.27-AB.1.d.** refer to the American Petroleum Institute API 650, Welded Steel Tanks for Oil Storage.

e. For Supporting Knowledge and Skills **K&S 1.27-AB.1.e.** refer to the following American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) documents:

- ASHRAE 15, Safety Code for Mechanical Refrigeration
- ASHRAE 51, Laboratory Methods for Testing Fans for Rating
- ASHRAE 62, Ventilation Requirements for Acceptable Indoor Air Quality
- ASHRAE 90, Energy Conservation in New Building Design
- ASHRAE 100, Energy Conservation in Existing Building Design

f. For Supporting Knowledge and Skills **K&S 1.27-AB.1.f.** refer to the following American Society of Mechanical Engineers (ASME) documents:

- ASME B31.1, Power Piping
- ASME B31.3, Chemical Plant and Petroleum Refinery Piping
- ASME N510, Testing of Nuclear Air Cleaning Systems
- ASME NQA-1, Quality Assurance Requirements for Nuclear Facilities Application (contains revisions from ASME NQA-2, Quality Assurance Program Requirements for Nuclear Facilities Application)
- ASME B 16, Fitting, Flanges, and Valves
- ASME BPVC, Boiler and Pressure Vessel Code

g. For Supporting Knowledge and Skills **K&S 1.27-AB.1.g.** refer to the following American Society of Testing and Materials (ASTM) documents:

- ASTM A 312, Standard Specification for Seamless and Austenitic Stainless Steel Pipe
- ASTM G 46, Standard Practice for Examination and Evaluation of Pitting Corrosion.

h. For Supporting Knowledge and Skills **K&S 1.27-AB.1.h.** refer to the following Society of Automotive Engineers documents:

- SAE J30, Fuel and Oil Hoses
- SAE J827, Cast Steel Shot
- SAE J1053, Steel Stamped Nuts of One Pitch Thread Design
- SAE J1900, Seals-Bond Test Fixture and Procedure
- SAE J1945, Cross-Tooth Companion Flanges, Type T
- SAE J2016, Chemical Stress Resistance of Polymers
- SAE J2045, Tube/Hose Assemblies
- SAE J2096, Categorization of Low-Carbon Automotive Sheet Steel
- SAE HS 2100, Numbering System for Standard Drills, Standard Taps and Reamers

4. Practice Exercise

a. Which document provides design criteria for routine use in the design of steel frame buildings? (K&S 1.27-AB.1.a.)

b. To determine how many chemical eyewash stations are required for a facility which document would provide guidance?

b. Which document contain information on limitation placed on pipes carrying solutions uranium 233? (K&S 1.27-AB.1.c.)

c. Which organization provides documents for the control and application of air conditioning systems? (K&S 1.27-AB.1.e.)

d. Which document provide procedures and guidance for testing of ventilation system to ensure acceptable air quality? (K&S 1.27-AB.1.e.)

   1) ASHRAE 15, Safety Code for Mechanical Refrigeration

   2) ASHRAE 51, Laboratory Methods for Testing Fans for Rating

   3) ASHRAE 62, Ventilation Requirements for Acceptable Indoor Air Quality

   4) ASHRAE 90, Energy Conservation in New Building Design

e. Which document provide guidance for the number of HEPA filters that must be tested in a nuclear facility? (K&S 1.27-AB.1.f.)

f. Which document provides information on the workmanship and repair of piping? (K&S 1.27-AB.1.g.)

g. To research the testing requirements for tubing installed on a gasoline engine, which document would you use? (K&S 1.27-AB.1.h.)

5. Practice Exercise Answers

a. Which document provides design criteria for routine use in the design of steel frame buildings? (K&S 1.27-AB.1.a.)

AISC S 326 (S328-86), Specifications for Structural Steel Building Load and Resistance Factor Design

b. To determine how many chemical eyewash stations are required for a facility which document would provide guidance?

ANSI Z358.1, Emergency Eyewash and Shower Equipment

b. Which document contain information on limitation placed on pipes carrying solutions uranium 233? (K&S 1.27-AB.1.c.)

ANS 8.9, Nuclear Criticality Safety Criteria for Steel Pipe Intersections Containing Aqueous Solutions of Fissile Material

c. Which organization provides documents for the control and application of air conditioning systems? (K&S 1.27-AB.1.e.)

ASHRE American Society of Heating, Refrigeration, and Air Conditioning Engineers

d. Which document provide procedures and guidance for testing of ventilation system to ensure acceptable air quality? (K&S 1.27-AB.1.e.)

1) ASHRAE 15, Safety Code for Mechanical Refrigeration

2) ASHRAE 51, Laboratory Methods for Testing Fans for Rating

3) **ASHRAE 62, Ventilation Requirements for Acceptable Indoor Air Quality**

4) ASHRAE 90, Energy Conservation in New Building Design

e. Which document provide guidance for the number of HEPA filters that must be tested in a nuclear facility? (K&S 1.27-AB.1.f.)

ASME N510, Testing of Nuclear Air Treatment Systems

f. Which document provides information on the workmanship and repair of piping? (K&S 1.27-AB.1.g.)

   ASTM A 312, Standard Specification for Seamless and Austenitic Stainless Steel Pipe

g. To research the testing requirements for tubing installed on a gasoline engine, which document would you use? (K&S 1.27-AB.1.h.)

   SAE J2045, Tube/Hose Assemblies - Standard

AC. **Competency 1.28**

Mechanical systems (FAC# 1.21) personnel shall demonstrate a familiarity level knowledge of the various computer applications used in mechanical systems engineering.

1. Supporting Knowledge and Skills

   a. Identify and discuss at least one of the major computer codes used in mechanical systems modeling.

   b. Discuss the application of computer-aided design (CAD) as it relates to mechanical system design.

   c. Describe the use of computers in the monitoring and control of mechanical systems.

2. Self-Study Information

Competency 1.28 addresses the familiarity level knowledge of the use of computers in the Mechanical Systems engineering.

The supporting material for the Self-Study Activities include the following documents:

- Considine, Douglas M., P.E. (1993). Process/Industrial Instruments & Control Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-012445-0. Section 3, Controllers.
- McGraw-Hill Book Company (1978). Marks' Standard Handbook for Mechanical Engineers. New York, NY: McGraw-Hill, Inc. ISBN 0-07-004123-7. Chapter 2, Computers.

Computer codes used in mechanical systems modeling

Problem oriented computer languages have been developed for virtually every discipline of engineering. Typically these languages deal with specialized applications. Some of which deal with simulation and more recently distributed control systems for plant processes. Some of the typical engineering problem oriented computer languages are:

MIMIC	STRUDL
CSSLIII	BRIDGE
SCEPTRE	COGO
STRESS	

Computer-Aided Design (CAD)

Computer Aided Design (CAD) refers to the use of computers in converting the initial idea for a product or system into a detailed engineering design. They are an electronic alternative to traditional drafting boards and offer substantial features which are nearly impossible to accomplish using their paper analogs. Some of the tasks made simpler using CAD include the enlargement, compress and rotate objects. Another use for CAD is using them in combination with other engineering programs and applying various conditions to a model to determine graphically how the created object or system would respond to real-world conditions. An example would be how a bridge would deform under various loads and stresses. When these studies or analyses were manually done it could take many hours whereas it only takes seconds or minutes when CAD is used. When these analysis and studies are performed on the computer it is commonly referred to as Computer Aided Engineering (CAE).

c. Describe the use of computers in the monitoring and control of mechanical systems.

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **1.28-AC.1.a**. refer to:
   - Considine, Douglas M., P.E. (1993). <u>Process/Industrial Instruments & Control Handbook</u>. New York, NY: McGraw-Hill, Inc. ISBN 0-07-012445-0. Section 3, Controllers.
   - McGraw-Hill Book Company (1978). <u>Marks' Standard Handbook for Mechanical Engineers</u>. New York, NY: McGraw-Hill, Inc. ISBN 0-07-004123-7. Chapter 2, Computers.

b. For Supporting Knowledge and Skills **1.28-AC.1.b.** refer to:
   - Considine, Douglas M., P.E. (1993). <u>Process/Industrial Instruments & Control Handbook</u>. New York, NY: McGraw-Hill, Inc. ISBN 0-07-012445-0. Section 3, Controllers
   - Parker, Sybil P. (1992). <u>McGraw-Hill Encyclopedia of Engineering</u>. New York, NY: McGraw-Hill, Inc. ISBN 0-07-051392-9. Computer Aided Design.

c. For Supporting Knowledge and Skills **1.28-AC.1.c.** refer to:

This page is intentionally blank.

AD. Competency 1.29

Mechanical systems (FAC# 4.9) personnel shall demonstrate the ability to apply materials inspection techniques in the verification of mechanical system integrity.

1. Supporting Knowledge and Skills

a. Using system specifications, including a system diagram, determine the key information for a hydrostatic test on that system.

b. Using a work package, determine the appropriate tests needed to ensure proper installation of the mechanical system.

c. Using component information, describe the load tests required prior to lifting that component.

2. Self-Study Information

Competency 1.29 addresses the demonstrate the ability of the inspection techniques in the verification of mechanical system integrity.

The supporting material for the Self-Study Activities include the following documents:

- **Nayyar, Mohinder, P.E. (1992). <u>Piping Handbook</u>. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8.**

Hydrostatic test

A very important task to be performed when putting a new piping system into service or after service to an existing system is the hydrostatic test. This is a recommended test which subjects the system to cyclical and constant pressures over a specified time period. The test pressure must not be so high as to damage components of the system but high enough that bad joints and leaks can be found prior to placing the system into service.

Hydrostatic test pressure is the pressure applied to a system to test the pressure boundary of the system. All non-isolatable components within the test bound are to be elevated for limitations of the maximum test pressure. The maximum test pressure shown is hydrostatic unless identified by the Piping Code (P-Code). Individual components can be bench tested when removed from the system for maintenance or repair. When the system has been re-installed the entire system can be pressurized and tested to ensure the system has adequate pressure boundary integrity.

Work package to ensure proper installation of the mechanical system

Load tests

Prior to lifting any component with a crane or hoist, the equipment must be inspected to ensure the component can be safely moved with the crane or hoist to be used. The tests that are performed are dependent upon the type of equipment to be used to perform the lifting. The types of test that are performed include: operational tests; tests and inspection of moving parts; latches; rated load tests; visual inspections; and verification that the crane or hoist rating is sufficient to lift the component in question.

Specific procedures and guidelines must be followed at each facility to identify the tests that must be performed prior to lifting any load. Review of local procedures on Hoisting and Rigging is mandatory prior to determining which load tests must be completed. Generic requirements can be found in the cited references.

3. References

NOTE: For information regarding the Supporting Knowledge and Skills refer to the Self-Study Information section of this competency.

a. For Supporting Knowledge and Skills **1.29-AD.1.a.** refer to:
   - Nayyar, Mohinder, P.E. (1992). Piping Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8. Part C, Water Systems Piping, Part D, Non-Metallic Piping.

b. For Supporting Knowledge and Skills **1.29-AD.1.a.** refer to:

c. For Supporting Knowledge and Skills **1.29-AD.1.c.** refer to:
   - U.S. Department of Energy. Department of Energy Hoisting and Rigging Manual (DOE/ID-10500). Washington, DC: U.S. Department of Energy.
   - U.S. Department of Energy (1995). Hoisting and Rigging (DOE-HDBK-1090-95). Washington, DC: U.S. Department of Energy Environment, Safety, and Health.

This page is intentionally blank.

U.S. Department of Energy
Technical Qualifications

Mechanical Systems Topical Area

Self-Study Guide
Glossary

Appendix A

June 1996

This page is intentionally blank.

Appendix A Glossary

American National Standards Institute (ANSI)	Voluntary membership organization that develops national consensus standards for a large number of devices and procedures.
Anchor	A rigid restraint which prevent rotation or displacement of a pipe.
Cavitation	The formation of vapor bubbles in a low pressure region of a pump and their subsequent collapse on a high pressure region. Cavitation can have a significant effect on pump performance. Cavitation lowers a pumps performance resulting in fluctuating flow rate and discharge pressure. Cavitation can also destroy pump internals.
CFR (Code of Federal Regulations)	Includes the rules that are promulgated under U.S. law, published in the Federal Register, and actually in force at the end of a calendar year.
Corrosive	A substance that causes visible destruction or permanent changes in human tissue at the site of contact.
Density	Ratio of the mass of a material to its volume. May have a variety of units including lbm/ft^3 or g/cm^3.
Dewpoint	Temperature a which the vapor condenses when it is cooled at a constant pressure.
Energy	Capacity for doing work. Various forms of energy include chemical, electrical, geothermal, kinetic, nuclear, potential, solar, wind, and others.
Expansion joint	A flexible piping component designed to allow for thermal expansion of a pipe.
Fluid	Any substance that flows, i.e., a liquid or a gas.
Gas	State of matter in which the material has a low density and viscosity; can expand and control in response to changes in temperature and pressure.

Gas binding	The condition in a centrifugal pump when the pump casing is filled with non-condensable gases or vapors to the point where the impeller is no longer able to contact enough liquid to function correctly.
Gram	Metric unit of mass (453.6 grams equal 1 pound).
Hanger	Devices designed to transfer the load from a pipe or component to a structural member.
HEPA (High-Efficiency Particulate Air) Filter	An extended medium, dry-type filter with a particle removal efficiency of no less than 99.97 percent of 0.3 micron particles.
Inches of Mercury	Unit used in measuring pressure that is equal to the pressure exerted by a column of mercury 1 inch high at a standard temperature.
Inert Gas	Gas that does not normally combine chemically with the base metal or filler metal.
Joule	Unit of energy used in describing a single pulsed output of a laser. It is equal to 1 watt/second or 0.239 calories.
Kelvin Scale	Fundamental temperature scale, in which the temperature measure is based on the average kinetic energy per molecule of perfect gas. The zero of the Kelvin scale is -273.18° Celsius.
Kinematic Viscosity	The ratio of the absolute viscosity to the mass density.
Kinetic Energy	Energy possessed by a moving body, equal to one-half its mass multiplied by the square of its velocity.
Laminar Flow	Streamlined flow in which the entire body of fluid within a designated space moves with approximate uniform velocity in one direction along parallel flow lines. Typically occurs when the Reynolds number is less than 2000.
Liquid	State of matter in which the substance is a formless fluid that flows in accord with the laws of gravity.
Maintenance	Activities intended to ensure that facilities and equipment should be in good operating condition.

Makeup Air	Clean, tempered outdoor air supplied to a work space to replace air removed by exhaust ventilation or some industrial process.
Manometer	Instrument for measuring pressure of gases or vapors by changing the level of a fluid in a tube. It consists essentially of a U-tube partially filled with a liquid and constructed so that the amount of displacement of the liquid indicates the pressure being exerted on the instrument.
Mass	Quantity of matter. The units of measure are the gram and the pound.
Net Positive Suction Head (NPSH)	To avoid cavitation in pumps, the pressure of the fluid at all points within the pump must remain above the saturation pressure. The net positive suction head is the difference between the suction pressure and the saturation pressure of the fluid being pumped.
Pipe	A tube with a round cross section. Must meet the dimensional requirements for pipe size in accordance with ANSI B36.10 and ANSI B36.19.
Pitot Tube	Tube with a short right, angled bend, used with a manometer for measuring the velocity of fluids (liquid or gas) by means of pressure difference.
Potential Energy	Energy possessed by a body due to its relative height, equal to the mass multiplied by the height multiplied by gravitational constant.
Power	Time rate at which work is done; units are the watt (1 joule per second) and the horsepower (33,000 foot-pounds per minute).
Pressure	The force acting per unit area. Typical units are psi (pounds forces per square inch), lbf/ft^2 (pounds force per foot square), atm (atmospheres), Pa (paschal), or N/m^2 (newton per square meter).
Relative Humidity	Ratio of the quantity of water vapor present in air to the quantity that would saturate it at any specific temperature.

Relief Valve	An automatic pressure relieving device actuated by static pressure or temperature upstream of the valve. The valve opens in proportion to the increase over set pressure or temperature. Relief valves are normally used in liquid service.
Run-Out	The condition that exists when the pump differential pressure or head drops below the design minimum discharge differential pressure or head.
Safety Valve	An automatic pressure relieving device actuated by static pressure upstream of the valve and characterized by rapid full opening pop. Safety valves are normally used in gas or vapor service.
Schedule number	The approximate value of the ratio of the pressure to the allowable stress multiplied by 1000.
Shut-Off Head	For a given pump operating at a constant speed, the flow rate through the pump is dependent upon the differential pressure or head developed by the pump. Shut-Off Head is the maximum differential pressure or head that can be developed by a pump operating at a constant set speed and it is the pressure that a pump can no longer move fluid.
Slurry	A two phase mixture of solids and liquids.
Specific gravity	The ratio of the weight of a substance to an equal volume of water at standard conditions of temperature and pressure. The value is unitless.
Specific volume	The volume of a unit mass of a fluid. Typical units are ft^3/lbm (cubic feet per pound mass).
Specific weight	The weight of a unit volume of a fluid. Typical units are lbm/ft^3 (pound mass per cubic foot).
Stress	Physical, chemical, or emotional factors that cause bodily or mental tension and may be a factor in disease or fatigue.
Temperature, Dry Bulb	Temperature of a gas or mixture of gases indicated by an accurate thermometer after correction for radiation.

Temperature, Wet Bulb	Thermodynamic wet-bulb temperature is the temperature at which liquid or solid water, by evaporating into air, can bring the air to saturation at the same temperature and pressure.
Vapor	The gaseous form of a substance that is normally in the solid or liquid state (at room temperature and pressure).
Vapor Density	Weight of a vapor per unit volume at any given temperature and pressure.
Vapor Pressure	Force exerted at any given temperature by a vapor, either by itself or in a mixture of gases; measured at the surface of an evaporating liquid.
Ventilation	Causing fresh air to circulate to replace foul air simultaneously removed.
Viscosity	The internal friction of flowing fluid molecules.
Watt (w)	Unit of power, equal to 1 joule per second.

This page is intentionally blank.

U.S. Department of Energy
Technical Qualifications

Mechanical Systems Topical Area

Self-Study Guide
Training-to-Competency Matrices

Appendix B

TO BE DEVELOPED

June 1996

This page is intentionally blank.

U.S. Department of Energy
Technical Qualifications

Mechanical Systems Topical Area

Self-Study Guide
References

Appendix C

June 1996

This page is intentionally blank.

Appendix C References

a. The following references are subject to Change Control[1]. Users should reference the most current revision.

1. DOE Fundamentals Handbook Thermodynamics, Heat Transfer, and Fluid Flow, (DOE-HDBK-1012/3-92) Volume 3 of 3.
2. DOE Fundamentals Handbook Instrumentation and Control (DOE-HDBK-1013/1-92) Volume 1 of 2.
3. DOE Fundamentals Handbook Engineering Symbology, Prints, and Drawings (DOE-HDBK-1016/1-93), Volume 1 of 2.
4. DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/1-93) Volume 1 of 2
5. DOE Fundamentals Handbook Mechanical Science (DOE-HDBK-1018/2-93) Volume 2 of 2.
6. DOE Topical Area Instrumentation and Control Self-Study Guide (SR-TA-I&C-SSG-01)
7. DOE Topical Area Mechanical Science Self-Study Guide (SR-TA-MES-SSG-01)
8. DOE Order 5440.1C National Environmental Policy Act
9. DOE Order 5450.4
10. DOE Order 5480.1B Environment, Safety, and Health Program for Department of Energy Operations
11. DOE Order 4700.1, Chapter V
12. DOE Order 6430.1A, General Design Criteria
13. DOE-STD-1073-93-Pt.1 (1993). Guide for Operational Configuration Management Program
14. U.S. Department of Energy. Department of Energy Hoisting and Rigging Manual (DOE/ID-10500). Washington, DC: U.S. Department of Energy.
15. U.S. Department of Energy (1995). Hoisting and Rigging (DOE-HDBK-1090-95). Washington, DC: U.S. Department of Energy Environment, Safety, and Health.
16. U.S. Department of Energy (1990). Nuclear Standard, Quality Assurance Testing of HEPA Filters. Oakridge, TN: U.S. Department of Energy Office of Scientific and Technical Information.
17. Westinghouse Savannah River Company High Level Waste Operator Training Program Applied Heat Transfer and Fluid Flow Study Guide (WGACFA06)

[1] Change Control is a proceduralized process which ensures all changes are properly executed, from initiation of the change request through the approval, implementation, and incorporation into the next document revision.

18. Westinghouse Savannah River Site Engineering Requirement Document No. 15140-01-R, Field Fabrication and Installation of Pipe Supports.
19. Westinghouse Savannah River Site Engineering Requirement Document No. 15060-01-R, Process and Service Piping.
20. Westinghouse Savannah River Site Engineering Requirement Document No. 15140-01-R, Field Fabrication and Installation of Pipe Supports.
21. Westinghouse Savannah River Company Engineering Requirements Document Number 15060-01-R, Process and Service Piping, Section 9.1.3.1 Maximum Test Pressure.
22. Westinghouse Savannah River Site Engineering Requirement Document No. M-SPC-G-00021, Generic Specification of Mechanical Equipment.
23. Westinghouse Savannah River Site Engineering Requirement Document No. 15020-01-R, Installation of Mechanical Equipment.
24. Westinghouse Savannah River Site Engineering Requirement Document No. 15060-01-R, Process and Service Piping.
25. Westinghouse Savannah River Site Engineering Requirement Document No. 15250-01-R, Mechanical Insulation.
26. Westinghouse Savannah River Site Engineering Requirement Document No. 15020-01-R, Installation of Mechanical Equipment.
27. Westinghouse Savannah River Company Core Fundamentals Training Program Mechanical Science Level A Student Text (TTFGMS1A.H0100)
28. Westinghouse Savannah River Company Core Fundamentals Training Program Fluid Flow Level A Student Text (TTFGFF1A.H0100)
29. Westinghouse Savannah River Company Core Fundamentals Training Program Instrumentation and Controls Student Text (TTFGIC1A.H0100)
30. Westinghouse Savannah River Company High Level Waste Operator Training Heat Transfer and Fluid Flow Study Guide (NWMOG009.H0103)
31. Westinghouse Savannah River Company High Level Waste Operator Training Mechanical Science Study Guide (NWMOG015.H0102)
32. American Institute of Steel Construction (AISC) M 011 (MO16-89), Manual of Steel Construction Allowable Stress Design
33. American Institute of Steel Construction (AISC) N 690 (S327-84), Nuclear Facility - Steel Safety - related Structures for Design, Fabrication, and Erection
34. American Institute of Steel Construction (AISC) S 326 (S328-86), Specifications for Structural Steel Building Load and Resistance Factor Design
35. American National Standards Institute (ANSI) B79.1.
36. American National Standards Institute (ANSI) N 8.3, Criticality Accident Alarm System
37. American National Standards Institute (ANSI) Z 358.1, Emergency Eyewash and Shower Equipment

38. American National Standards Institute/ American Society of Mechanical Engineers ANSI/ASME OM-1 Requirements for Inservice Performance Testing of Nuclear Power Plant Pressure Relief Devices
39. American Nuclear Society (ANS) 15.1, Development of Technical Specifications for Research Reactors
40. American Nuclear Society (ANS) 8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials
41. American Nuclear Society (ANS) 8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors
42. American Nuclear Society (ANS) 8.9, Nuclear Criticality Safety Criteria for Steel Pipe Intersections Containing Aqueous Solutions of Fissile Material
43. American Nuclear Society (ANS) 59.51, Fuel Oil Systems for Emergency Diesel Generators
44. American Nuclear Society (ANS) 59.3, Nuclear Safety Criteria for Control Air Systems
45. American Nuclear Society (ANS) 59.1, Nuclear Safety-Related Cooling Water Systems in Nuclear Power Plants
46. American Petroleum Institute (API) 650, Welded Steel Tanks for Oil Storage
47. American Society of Heating, Refrigeration and Air-conditioning Engineers, (1993). ASHRAE Handbook Fundamentals. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
48. American Society of Heating, Refrigeration and Air-conditioning Engineers, (1991). ASHRAE Handbook HVAC Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
49. American Society of Heating, Refrigeration and Air-conditioning Engineers, (1992). ASHRAE Handbook HVAC Systems and Equipment. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
50. American Society of Heating, Refrigeration and Air-Conditioning Engineers, (1980). ASHRAE Handbook and Product Directory, 1977 Fundamentals. New York, NY: American Society of Heating, Refrigeration and Air-Conditioning Engineers.
51. American Society of Heating, Refrigeration and Air-Conditioning Engineers, (1992). ASHRAE Handbook and Product Directory, 1992 HVAC Systems and Equipment. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers. ISBN 0-910110-87-5.
52. American Society of Heating, Refrigeration and Air-conditioning Engineers, (1990). ASHRAE Handbook Refrigeration Systems and Applications. Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc.
53. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 15, Safety Code for Mechanical Refrigeration
54. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 34-67.
55. American Society of Heating, Refrigeration and Air-Conditioning Engineers

(ASHRAE) Standard 51, Laboratory Methods for Testing Fans for Rating

56. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 62, Ventilation Requirements for Acceptable Indoor Air Quality
57. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90, Energy Conservation in New Building Design
58. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 100, Energy Conservation in Existing Building Design
59. American Society of Mechanical Engineers (ASME) BPVC, Boiler and Pressure Vessel Code
60. American Society of Mechanical Engineers (ASME) Building Services Piping
61. American Society of Mechanical Engineers (ASME) B 16, Fitting, Flanges, and Valves
62. American Society of Mechanical Engineers (ASME) B31.1, Power Piping
63. American Society of Mechanical Engineers (ASME) B31.3, Chemical Plant and Petroleum Refinery Piping
64. American Society of Mechanical Engineers (ASME) N510, Testing of Nuclear Air Cleaning Systems
65. American Society of Mechanical Engineers (ASME) NQA-1, Quality Assurance Requirements for Nuclear Facilities Application (contains revisions from ASME NQA-2, Quality Assurance Program Requirements for Nuclear Facilities Application)
66. American Society of Testing and Materials (ASTM) Standards on Petroleum Products and Lubricants.
67. American Society of Testing and Materials (ASTM) A 312, Standard Specification for Seamless and Austenitic Stainless Steel Pipe
68. American Society of Testing and Materials (ASTM) G 46, Standard Practice for Examination and Evaluation of Pitting Corrosion
69. Electric Power Research Institute (1982). <u>EPRI CS-2725, Vibration & Balance Problems</u>.
70. Electric Power Research Institute. <u>EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room</u>.
71. Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 106
72. Facility Representative Advanced Nuclear Course (FRANC), Mechanical Systems and Components, Module 7
73. IEEE 379, Standard Application of the Single Failure Criterion to Nuclear Power Generating Station Class 1E Systems
74. Society of Automotive Engineers (SAE) HS 2100, Numbering System for Standard Drills, Standard Taps and Reamers
75. Society of Automotive Engineers (SAE) J30, Fuel and Oil Hoses
76. Society of Automotive Engineers (SAE) J827, Cast Steel Shot
77. Society of Automotive Engineers (SAE) J1053, Steel Stamped Nuts of One Pitch Thread Design

78. Society of Automotive Engineers (SAE) J1900, Seals-Bond Test Fixture and Procedure
79. Society of Automotive Engineers (SAE) J1945, Cross-Tooth Companion Flanges, Type T
80. Society of Automotive Engineers (SAE) J2016, Chemical Stress Resistance of Polymers
81. Society of Automotive Engineers (SAE) J2045, Tube/Hose Assemblies
82. Society of Automotive Engineers (SAE) J2096, Categorization of Low-Carbon Automotive Sheet Steel

b. The following references are NOT subject to "Change Control". Users may reference the identified revision or the most current revision. NOTE: if revised edition used pages and chapters may have changed.

1. Anders, James E. Sr. (1983). Industrial Hydraulics Troubleshooting. New York, NY: McGraw-Hill Book Company. ISBN 0-07-001592-9.
2. Brumbaugh, James E. (1983). Heating, Ventilating and Air Conditioning Library Volume 2. Indianapolis, IN: Bobbs Merrill Company, Inc. ISBN 0-672-23382-7.
3. Brumbaugh, James E. (1983). Heating, Ventilating and Air Conditioning Library Volume 3. Indianapolis, IN: Bobbs Merrill Company, Inc. ISBN 0-672-23383-5.
4. Bureau of Naval Personnel (Revised 1971). Fireman Rate Training Manual (NAVPERS 10520-D). Washington, DC: Training Publications Division. Stock Order No. 0500-137-1010.
5. Bureau of Naval Personnel (revised 1969). Refrigeration and Air Conditioning (NAVPERS 16163-A). Stock Ordering No. 0502-LP-080-8150.
6. Combustion Engineering (1967). Steam Tables Properties of Saturated and Superheated Steam - From 0.08865 to 15,500 LB per SQ IN. Absolute Pressure (Eleventh Printing). Windsor, CT: Combustion Engineering, Inc. ISBN 1-500-00002610. Call # TJ270.S8 1967.
7. Cheremisinoff, Nicholas P. (1982). Fluid Flow: Pumps, Pipes, and Channels. Ann Arbor, MI: Ann Arbor Science Publishers. ISBN 0-250-40432-X.
8. Considine, Douglas M., P.E. (1993). Process/Industrial Instruments & Control Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-012445-0.
9. Director, Office of Nuclear Safety, (1994). Safety Notice High-Efficiency Particulate Air Filters. Washington, DC: U.S. Department of Energy.
10. Garay, Paul N. (1990). Pump Application Desk Book. Lilburn, GA: Fairmount Press Inc. ISBN 0-88173-043-2.
11. Gollnick, Daniel A., (1994). Basic Radiation Protection Technology Third Edition. Altadena, CA: Pacific Radiation Corporation.
12. Granet, Irving, P.E. (1985). Thermodynamics and Heat Power. Reston, VA: Reston Publishing Company. ISBN 0-8359-7674-2.
13. Gunther, Raymond C. (1971). Lubrication. Philadelphia, PA: Chilton Book

Company. ISBN 0-8019-5526-2.

14. Keenan, J. H., F. G. Keyes, P. G. Hill, and J. G. Moore (1969). Steam Tables-Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases. New York, NY: John Wiley & Sons, Inc.
15. Lamit, Louis Gary (1984). Pipe Fitting and Piping Handbook. Englewood Cliffs, NJ: Prentise-Hall. ISBN 0-13-676602-1.
16. Littleton, Charles T. (1962). Industrial Piping. New York, NY: McGraw-Hill Book Company. ISBN 07-038126-7.
17. Loomis A. W., (1982). Compressed Air and Gas Data. Washington, NJ: Ingersoll-Rand Company.
18. McGraw-Hill Book Company (1978). Marks' Standard Handbook for Mechanical Engineers. New York, NY: McGraw-Hill, Inc. ISBN 0-07-004123-7.
19. Meister, D. and G. Rabideau, (1965). Human Factors Evaluation in System Development. New York, NY: John Wiley & Sons.
20. Naval Training Command (revised 1972). Machinist Mate 3 & 2 Rate Training Manual (NAVTRA 10524-D). Washington, DC: Naval Training Command. Stock Ordering No. 0502-052-6210.
21. Nayyar, Mohinder, P.E. (1992). Piping Handbook. New York, NY: McGraw-Hill, Inc. ISBN 0-07-046881-8.
22. Neale, M. J. (1993). Lubrication. Oxford, England: Butterworth-Heineman Ltd. ISBN 1-56091-392-4.
23. Olberg, Erik, Franklin D. Jones, Holbrook L. Horton, Henry H. Ryffel, Edited by Green Robert E. (1992). Machinery Handbook. New York, NY: Industrial Press Inc. ISBN 0-8311-2492-X.
24. Palmquist, Roland (1979). Answers on Blue Print Reading. Indianapolis, IN: Theodore Audel & Co. ISBN 0-672-23283-9.
25. Parker Fluidpower, (1991). Industrial Hydraulic Technology Bulletin 0232-B1. USA: Parker Hannifin Corporation. ISBN 1-55769-000-6
26. Parker, Sybil P. (1993). McGraw-Hill Encyclopedia of Engineering. New York, NY: McGraw-Hill, Inc. ISBN 0-07-051392-9.
27. Pease, Dudley A. and John J. Pippenger (1987). Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-13-061508-0. Call # TJ840.P4.
28. Power. The Engineer's Reference Library. New York, NY: McGraw-Hill Publications.
29. Saunders, E. A. D. (1988). Heat Exchangers: Selection, Design and Construction. Essex, England: Longman Scientific & Technical. ISBN 0-470-20870-8.
30. Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39.
31. Streeter, Victor L. and E. Benjamin Wylie. Fluid Mechanics, Eight Edition.
32. Stewart, Harry L. and Rex Miller (revised) (1991). Pumps. New York, NY: MacMillan Publishing Company. ISBN 0-02-614725-4.
33. Technology & Training Group. Industrial Pneumatics. Columbia, MD: General

Physics Corp.

34. UCRL 15673, Human Factors Design Guidelines for Maintainability of DOE Nuclear Facilities (available from NTIS)
35. Underwriters Laboratories Reports MH-2375, MH-3134, MH-3072, MH-2630, MH-6138
36. Underwriters Laboratory (UL) Standard 585, High-Efficiency Particulate Air Filter Units.
37. Walker, Rodger (1972). Pump Selection: A Consulting Engineers's Manual. Ann Arbor, MI: Ann Arbor Science Publishers Inc. ISBN 0-250-40005-7.
38. Underwriters Laboratories Inc. (1990). Standard for Safety - High-Efficiency, Particulate, Air Filter Units. Northbrook, IL: Underwriters Laboratories Inc. ISBN 1-55989-129-7.

c. The following references are cited in the DOE Fundamentals Handbooks and may provide additional information.

1. ANSI Y14.5M - 1982. Dimensioning and Tolerancing. American National Standards Institute.
2. Arnell, Alvin (1963). Standard Graphical Symbols. McGraw-Hill Book Company.
3. Babcock & Wilcox. Steam, Its Generations and Use. Babcock & Wilcox Co.
4. Benson & Whitehouse. Internal Combustion Engines. Pergamon.
5. Bureau of Naval Personnel (1970). Principles of Naval Engineering. Washington, D.C.: Training Publication Division, Naval Personnel Program Support Activity.
6. Cheremisinoff, Nicholas P. (1982). Fluid Flow: Pumps, Pipes, and Channels. Ann Arbor, MI: Ann Arbor Science Publishers. ISBN 0-250-40432-X.
7. E.E.U.A. Steam Trapping and Condensate Removal. Constable & Company.
8. Engineering Service Division (1952). Power Orientation Program. E.I.du Pont de Nemours and Company, Inc.

9. General Physics Corporation (1982). Academic Program for Nuclear Power Plant Personnel Volume III. Columbia, MD: General Physics Corporation. Library of Congress Card #A 326517.
10. General Physics Corporation (1982). Heat Transfer, Thermodynamics and Fluid Flow Fundamentals. Columbia, MD: General Physics Corporation. Library of Congress Card #A 326517.
11. General Physics Corporation. Chemistry, Health Physics and Nuclear Instrumentation, Volume IV. Columbia, MD: General Physics Corporation.
12. Jensen and Helsel (1979). Engineering Drawing and Design, Second Ed.. New York, NY: McGraw-Hill Book Company.
13. Marley. Cooling Tower Fundamentals and Applications. The Marley Company.
14. Mashe, George (1971). Systems Summary of a Westinghouse Pressurized Water Reactor. Westinghouse Electric Corporation.
15. NUS Training Corporation (1977). Nuclear Energy Training. NUS Corporation.
16. Scheel. Gas and Air Compression Machinery. McGraw/Hill.
17. Schweitzer, Philip A. (1972). Handbook of Valves. New York, NY: Industrial Press Inc. ISBN 0-8311-3026-1. Call #TS227.S39.
18. Skrotzki and Vopat. Steam and Gas Turbines. McGraw/Hill.
19. Stewart, Harry L. (1984). Pneumatics & Hydraulics. Theodore Audel & Company.
20. Stinson, Karl W. Diesel Engineering Handbook. Diesel Publications Incorporated.
21. TPC Training Systems (1974). Reading Schematics and Symbols. Barrington, IL: Technical Publishing Company.
22. United States Naval Institute (1951). Naval Auxiliary Machinery. Annapolis, MD: United States Naval Institute.
23. Westinghouse Technical Manual 1440-C307, SNUPPS, Pressurizer Instructions. Westinghouse.
24. Zappe, R.W. (1989). Valve Selection Handbook. Houston, TX: Gulf Publishing, Company.